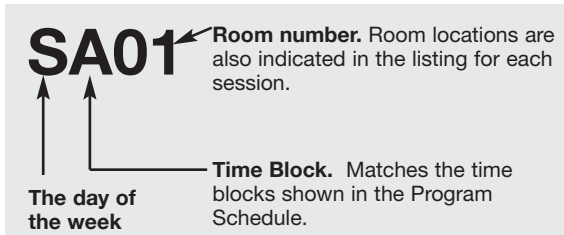


## How to Navigate the Technical Sessions

There are four primary resources to help you understand and navigate the Technical Sessions:

- This Technical Session listing, which provides the most detailed information. The listing is presented chronologically by day/time, showing each session and the papers/abstracts/authors within each session.

## The Session Codes



## Time Blocks

### Sunday - Monday

8:00am - 9:30am  
 10:00am - 10:50am  
 11:00am - 12:30pm  
 1:30pm - 3:00pm  
 3:10pm - 4:00pm  
 4:30pm - 6:00pm

### Tuesday

7:30am - 9:00am  
 9:30am - 10:20am  
 10:30am - 12:00pm  
 12:05pm - 1:35pm  
 2:00pm - 3:30pm  
 3:40pm - 4:30pm  
 4:35pm - 6:05pm

### Wednesday

8:00am - 9:30am  
 10:00am - 10:50am  
 11:00am - 12:30pm  
 3:20pm - 4:50pm

## Rooms and Locations /Tracks

All tracks / technical sessions will be held in the Phoenix Convention Center & Hyatt Regency Phoenix.

## Sunday, 8:00AM - 9:30AM

### SA01

North Bldg 121A

### Adjustable and Distributionally Robust Optimization

Sponsored: Optimization/Optimization Under Uncertainty

Sponsored Session

Chair: Dimitri Papadimitriou, Nokia Bell Labs, Brussels, 1190, Belgium

#### 1 - Distributionally Robust Risk-constrained Dynamic Asset Allocation Model

Tito Homem-de-Mello, Universidad Adolfo Ibáñez, Santiago, Chile,  
 Davi Valladao, Thuener Silva

Dynamic stochastic programming for asset allocation suffer from low out-of-sample performance due to discrepancies between the underlying stochastic processes and the actual prices. To enhance performance, we propose a distributionally robust dynamic portfolio optimization with one-period risk constraints considering transaction costs and a Markovian temporal dependence with ambiguous transition matrix. Assuming a ambiguity set based on a nominal transition matrix and the total variation distance measure, we develop a computationally tractable reformulation and present out-of-sample results.

#### 2 - Efficient Stochastic Gradient Descent for Distributionally Robust Optimization

Soumyadip Ghosh, IBM TJ Watson Research Center, 1101  
 Kitchawan Road, Route 134, Yorktown Heights, NY, 10598,  
 United States, Mark S. Squillante, Ebisa Wollega

We propose a new stochastic gradient descent algorithm to efficiently solve min-max formulations that arise naturally in distributionally robust learning. Current approaches do not scale well because the formulations include as decision variables a probability mass function over the whole collection of data samples. Our proposal is to approximate the optimization over the uncertainty set by subsampling the support, progressively increasing this support to cover the entire dataset as the iterates proceed. We develop asymptotic guarantees on how fast the support set should grow to optimally, in a strong statistical sense, balance the computational effort with the required level of accuracy.

#### 3 - Distributionally Robust Optimization with Decision Dependent Ambiguity Sets

Sanjay Mehrotra, Northwestern University, Dept of I. E. / M. S.  
 C246 Tech Inst, 2145 Sheridan Road, Evanston, IL, 60208-3119,  
 United States, Fengqiao Luo

We study distributionally robust optimization models, where the ambiguity sets of probability distributions can depend on the decision variables. These models arise in situations with endogenous uncertainty. Two-stage decision dependent stochastic programs are a special case. We give dual formulations for ambiguity sets based on moment constraints, Wasserstein metric, phi-divergence and multi-variate Kolmogorov-Smirnov sets. In the finite scenario case, the dual formulations have a finite number of constraints. In certain more general cases, the dual problems are non-convex semi-infinite programs.

#### 4 - Benders Decomposition for Adjustable Robust Optimization Problems

Dimitri Papadimitriou, Nokia Bell Labs, Rue du Charme 24,  
 Brussels, 1190, Belgium

Consider two-stage adjustable robust programs with continuous second-stage variables and covering constraints with both left and right-hand side uncertainty. Such programs model situations where, for instance, without requiring optimal production conditions, both allocation and production variables adjust (per-customer and per-location, respectively) to satisfy uncertain demands, and allocation decisions are constrained by local production. We analyze the properties of the resulting Affinely Adjustable Robust Counterpart (AARC) formulation when the decision-making policies are limited to (piecewise) affine rules, i.e., the continuous adjustable variables are approximated by affine function of the uncertain data. Then, we propose a robust formulation of the uncertain mixed-integer linear program that exploits its decomposable structure into first and second stage decision problems. Next, we detail an exact algorithm for the solving of such problems that relies on the Benders decomposition method while accounting for the properties of the extreme points characterizing polyhedral uncertainty sets. This method relies on dynamic cutting-plane generation. More precisely, under the relatively complete recourse assumption, it performs by iteratively generating optimality cuts/cutting planes (obtained from the dual subproblem), adding them to the master problem and solving the resulting master problem such that its lower and upper bounds converge and thus, an optimal solution of the original uncertain problem can be obtained. This paper also investigates possible strategies to reduce the convergence time of the Benders decomposition algorithm to the optimal solution by maintaining balance between the number of iterations and the number as well as the type of cuts produced at each iteration.

## ■ SA02

North Bldg 121B

### Joint Session OPT-Uncert/APS: Optimization in Statistics I

Sponsored: Optimization/Optimization Under Uncertainty

Sponsored Session

Chair: Robert Bassett, Naval Postgraduate School, Monterey, CA, United States

#### 1 - Variational Analysis of M-estimators

Johannes Royset, Naval Postgraduate School, Operations Research Department, Monterey, CA, 93943, United States

We present a framework for construction, analysis, and computations of M-estimators in the presence of soft information about shape, support, continuity, slope, location of modes, density values, and other conditions that, individually or in combination, restrict the family of estimates under consideration. The framework also leads to plug-in estimators with the exceptional property that convergence of densities and regression functions implies convergence of modes, maximizers, high-likelihood events, and related quantities. We illustrate the approach with several applications.

#### 2 - Approximation of Maximum a Posteriori Estimators Using Bayes Estimators

Julio Alejandro Deride Silva, Sandia National Laboratories, CERL/111, MS/1327, P.O. Box 5580, Albuquerque, NM, 87185-1327, United States, Robert Bassett

In this talk, we present an approximation scheme for statistical estimation using variational analysis techniques. In particular, we focus on the folk theorem that characterizes Maximum a posteriori estimators as a limit of a sequence of Bayes estimators under 0-1 loss. We first provide a counterexample, which shows that in general, this claim fails to hold true. Secondly, since both estimators are defined in terms of optimization problems, the tools of variational analysis find a natural application to Bayesian point estimation, and we analyze the convergence using notions of hypo-convergence. Finally, we provide conditions when this result holds true

#### 3 - Coupled Learning Enabled Optimization

Junyi Liu, University of Southern California, 30 Virginia Avenue, Los Angeles, CA, 91107, United States, Guangyu Li, Suvrajeet Sen

Empowered by machine learning techniques, diagnostic and predictive analytics are usually followed by decision-making problems in prescriptive analytics. We extend the above sequential prediction-optimization paradigm to a case in which prediction and optimization model are coupled so that the parameter estimation model can guide the optimization models to achieve higher levels of performance. Under certain assumptions on the problem and training data set, we show that the sequence of solutions provided by the coupled algorithm converges to the first-order stationary point of the original stochastic optimization problem.

#### 4 - Phase Retrieval Denoising via Rapid Eigenvalue Computation of Evolving Matrices

Will Wright, University of California, Davis, CA, United States, Zhaojun Bai

Phase retrieval has a wide range of solution methods, yet few exist for handling noisy observations (aka, phase retrieval denoising) without imposing additional restrictions such as signal sparsity. We focus on a recent phase retrieval denoising model: the gauge dual of the PhaseLift model (GD-PL). GD-PL can be solved with subgradient descent, with the main cost being a sequence of evolving eigenvalue problems. We establish optimal methods for handling this sequence of eigenvalue problems. We also establish probabilistic results of the optimality of the signal returned by the subgradient descent algorithm.

#### 5 - Fused Density Estimation for Data on Infrastructure Networks

Robert Bassett, Naval Postgraduate School, 1 University Circle, Monterey, CA, United States, James Sharpnack

We introduce a new method for nonparametric density estimation on geometric networks. By penalizing maximum likelihood estimation with a total variation penalty, we avoid overfitting and the dirac curse. We provide results which reduce the search space for the estimator from infinite dimensional function space to the finite-dimensional setting, and further demonstrate its computational tractability. We then focus on the asymptotic convergence rate of this density estimation method. Lastly, we review applications to infrastructure networks.

## ■ SA03

North Bldg 121C

### Creating Value in Innovation

Sponsored: Technology, Innovation Management & Entrepreneurship

Sponsored Session

Chair: Tian Chan, Emory University's Goizueta Business School, Atlanta, GA, 30322, United States

#### 1 - The Firm Productivity Implications of Technology Licensing: Evidence from Developing Asian Economy Manufacturing Firms

Xiaojin Liu, 100 Darden Boulevard, Charlottesville, VA, 22903, United States, Anant Mishra

This study focuses on the productivity implication of technology licensing in developing Asian economy manufacturing firms, and examines how it is affected by infrastructural factors in a firm's internal and external environment.

#### 2 - Delegating Innovation

Morvarid Rahmani, Georgia Institute of Technology, 800 West Peachtree Street NW, Room 4246, Atlanta, GA, 30308-1149, United States, Karthik Ramachandran

In many contexts such as product design and advertising, clients seek the expertise of external providers to generate innovative solutions for their business problems. In this paper, we explore how the client's flexibility in terminating the project can influence the progress and efficiency of the delegated innovation.

#### 3 - Search and Sequential Innovation in Mobile App Development

Nilam Kaushik, University College London, London, 02115, United Kingdom, Bilal Gokpinar

The process of search, identification, and acquisition of knowledge is essential for the success of products. This paper empirically characterizes the sequential innovation process in the setting of mobile app development using novel text-mining techniques.

#### 4 - Designing Internal Innovation Contests

Lakshminarayana Nittala, University of California-San Diego, Rady School of Management, 9500 Gilman Drive, La Jolla, CA, 92093, United States, Sanjiv Erat, Vish Krishnan

Firms can use internal contests to source solutions to problems associated with innovation. However, designing such contests involves nuanced understanding of the impact of such contests on the on-going projects within the firm. Optimal contest design is discussed along with managerial implications.

## ■ SA04

North Bldg 122A

### Joint Session OPT/Practice Curated: Theory and Applications of MIP

Sponsored: Optimization/Integer and Discrete Optimization

Sponsored Session

Chair: Haochen Luo, Texas A&M University, College Station, TX, 77843-3131, United States

#### 1 - A Bounded Formulation for the School Bus Scheduling Problem

Liwei Zeng, Northwestern University, 2145 Sheridan Road, IEMS Department, Evanston, IL, 60208, United States, Karen Smilowitz, Sunil Chopra

This paper proposes a new formulation for the school bus scheduling problem (SBSP) which optimizes starting times for schools and associated bus routes to minimize transportation cost. Specifically, the problem determines the minimum number of buses required to complete all bus routes under the constraint that routes for the same school must arrive within a set time window before that school starts. We present a new integer linear programming (ILP) formulation for this problem which is based on a time-indexed formulation. We develop a randomized rounding algorithm based on the linear relaxation of the ILP that yields near-optimal solutions for large-scale problem instances.

#### 2 - Integer Programming for Learning Directed Acyclic Graphs

Hasan Manzour, University of Washington, Seattle, WA, United States, Simge K. Á. Kyavuz, Ali Shojaie

Bayesian Networks (BNs) are probabilistic graphical models that represent causal relationships among a set of random variables in the form of a Directed Acyclic Graph (DAG). We study the problem of DAG structural learning of a BN from observational data where the underlying causal mechanism in the network is linear. We propose a new optimization model for this learning problem and discuss the statistical implications of L1 versus L0 penalty in our model. The computational results, tested on both synthetic and real datasets, demonstrate that the proposed model is computationally more efficient to learn the optimal DAG when compared with the existing mathematical models in the literature.

### 3 - An MIP Approach to Finding Optimum Search Schemes for Approximate String Matching

Haochen Luo, Texas A&M University, 3131 TAMU,  
College Station, TX, 77843-3131, United States, Kiavash Kianfar,  
Christopher Pockrandt, Bahman Torkamandi, Knut Reinert

Finding approximate occurrences of a pattern in a text using a full-text index is a central problem in bioinformatics. Use of search schemes (partitioning the pattern and searching the pieces in certain orders with given bounds on errors) can yield significant speed-ups. However, finding optimal search schemes is a difficult combinatorial optimization problem. Here for the first time, we propose a mixed integer program (MIP) capable to solve this optimization problem for Hamming distance with given number of pieces. Our experiments show that the optimal search schemes found by our MIP significantly (up to 35 times) improve the performance of search in index upon previous ad-hoc solutions.

## ■ SA05

North Bldg 122B

### Joint Session OPT/Practice Curated: Sparse Semidefinite Programs with Machine Learning Applications

Sponsored: Optimization/Linear and Conic Optimization

Sponsored Session

Chair: Somayeh Sojoudi, University of California, Berkeley, Berkeley, CA, 94703, United States

Co-Chair: Richard Zhang, UC Berkeley, Berkeley, CA, 94709, United States

#### 1 - Empirical Bayes Estimation of Parametric Gaussian Priors

Martin Skovgaard Andersen, Technical University of Denmark,  
Asmussens Allé, Kgs. Lyngby, 2800, Denmark

In Gaussian linear models, a maximum a posteriori estimate of a set of unknown parameters depends on a prior distribution that is typically unknown. Assuming that this prior is Gaussian with a structured or sparse precision matrix, we investigate the use of empirical Bayes estimation to estimate the prior directly from data. We also propose a method to solve the resulting estimation problem, which is a nonlinear semidefinite optimization problem, and demonstrate the usefulness of the approach with some numerical examples.

#### 2 - SDP Formulations for Fairness in Unsupervised Learning

Mahbod Olfat, PhD Student, University of California-Berkeley,  
1433 Dwight Way, Unit C, Berkeley, CA, 94702, United States,  
Anil Aswani

Though there is a growing body of literature on fairness for supervised learning, the problem of incorporating fairness into unsupervised learning has been less well-studied. This paper studies fairness applied to PCA. We first present a definition of fairness for dimensionality reduction, which can be interpreted as saying that a reduction is fair if information about a protected class cannot be inferred from the dimensionality-reduced data points. Next, we develop convex optimization formulations that can improve the fairness (with respect to our definition) of PCA and kernel PCA. These formulations are SDP's, and we demonstrate the effectiveness of our formulations using several datasets.

#### 3 - Linear-time Algorithm for Learning Large-scale Sparse Graphical Models

Richard Zhang, UC Berkeley, 621 Sutardja Dai Hall, University of California, Berkeley, CA, 94709, United States, Salar Fattahi,  
Somayeh Sojoudi

The sparse inverse covariance estimation problem is commonly solved using an  $l_1$ -regularized Gaussian maximum likelihood estimator known as "graphical lasso". This talk describes a Newton-CG algorithm to efficiently solve graphical lasso for large datasets. Assuming that the thresholded sample covariance matrix is sparse with a sparse Cholesky factorization, we prove that the algorithm converges to an  $\epsilon$ -accurate solution in  $O(n \log(1/\epsilon))$  time and  $O(n)$  memory. The algorithm is highly efficient in practice: we solve graphical lasso problems with as many as 200,000 variables to 7-9 digits of accuracy in less than an hour on a standard laptop computer running MATLAB.

### 4 - Control-theoretic Analysis of Smoothness for Stability-certified Reinforcement Learning

Ming Jin, UC Berkeley, Cory 406, Berkeley, CA, 94720,  
United States

It is critical to obtain stability certificate before deploying RL in real-world mission-critical systems. This work justifies smoothness as an important property for stability-certified RL from a control-theoretic perspective. The smoothness margin can be obtained by solving a feasibility problem based on SDP for both linear and nonlinear dynamical systems, and it does not need to access the exact parameters of the learned controllers. Numerical evaluation on nonlinear and decentralized frequency control for large-scale power grids is demonstrated using (deep) neural-network policies. The study opens up new opportunities for robust Lipschitz continuous policy learning.

## ■ SA06

North Bldg 122C

### Grey Box Optimization

Sponsored: Optimization/Computational Optimization and Software  
Sponsored Session

Chair: Fani Boukouvala, Georgia Institute of Technology, Atlanta, GA, 30312, United States

#### 1 - RBF Surrogate Global Optimization in Serial and Parallel that Dramatically Outperform Gaussian Process (ego) Methods in Dimensions Over 9

Christine A. Shoemaker, Distinguished Professor, National  
University of Singapore, 107 Clementi Road, Block F. 09-01,  
Singapore, 129790, Singapore

We show comparisons between Gaussian Process (GP) and Radial Basis Functions (RBF) based surrogate global optimization on a large number of problems (including deep learning). The comparisons have multiple versions of GP-EI (EGO). The RBF methods include the DYCORDS-MRS acquisition function. With a fixed number of objective function evaluations, multiple trials, and a large number of problems, the GP-EI solutions are much worse than RBF-DYCORDS on average for dimensions 10, 20, 30, and 40. The reasons for those differences are quantitatively assessed and explained. We also show RBF parallel results and beneficial impact of dynamic replacement of global surrogate by multiple local RBF surrogates

#### 2 - Integrating Sensitivity Analysis in Computationally Expensive Black-box Optimization

Juliane Mueller, Lawrence Berkeley National Lab,  
2453 Bonar Street, Berkeley, CA, 94702, United States

Computationally expensive simulations are used in many fields of science to study complex natural phenomena. These simulations often contain a large number of parameters that must be optimized efficiently because the simulation's computational expense limits the number of parameter combinations that can be tried. The effect of many of these parameters on the simulation's output may not be well understood. In this talk, we present a method in which we integrate sensitivity analysis (SA) in the iterative sampling procedure of an adaptive surrogate model optimization algorithm. We compare the approach with a method that does not use the SA information and a two-stage approach.

#### 3 - Combine Surrogate Based Global Search and Trust Region Local Search for Improved Global Optimization

Limeng Liu, PhD Student, National University of Singapore, 21  
Lower Kent Ridge Rd, Singapore, 138600, Singapore,  
Christine A. Shoemaker

We design a new surrogate based algorithm for black-box continuous function optimization. Since Local minima in the global surrogate are promising regions for the global optimum, our algorithm intelligently selects among local minima in the surrogate as starting points for derivative free trust region based local search (ORBIT). Results show that our algorithms have good performance with high accuracy especially on high dimensional problems. There is a convergence proof for our algorithm. In addition to high accuracy, this framework has an advantage of easy parallelization.

#### 4 - Spatial Branch-and-Bound Data-Driven Optimization Using Surrogate Approximations

Jianyuan Zhai, Georgia Tech University, Atlanta, GA, United States

Abstract not available.



## ■ SA07

North Bldg 123

### Optimization in Social Networks

Sponsored: Optimization/Network Optimization

Sponsored Session

Chair: Balabhaskar Balasundaram, Stillwater, OK, 74078, United States

#### 1 - Generalizations of the Dominating Set Problem on Social Networks

Rui Zhang, University of Colorado, Boulder, CO, 80309, United States, Subramanian Raghavan

The positive influence dominating set problem is a generalization of the dominating set problem that arises on social networks. First, we show that it can be solved in linear time on trees. Next, we provide a tight and compact extended formulation, and derive a complete description of its polytope on trees. The formulation is also valid on general graphs, thus providing a new and stronger one. Facet defining conditions for the new inequalities are provided. A computational study is conducted.

#### 2 - On Detecting Second-order 2-clubs in Graphs

Yajun Lu, Oklahoma State University, Stillwater, OK, United States, Baski Balasundaram

This talk will discuss a decomposition approach to detect a type of “second-order” 2-club in graphs, called an  $r$ -robust 2-club. The problem is to find a subset of vertices with maximum cardinality such that there are at least  $r$  internally vertex-disjoint paths of length at most two in the induced subgraph. Complexity results, formulations, and preprocessing ideas will be discussed. Effectiveness of the algorithmic techniques in solving the problem will be demonstrated on a test-bed of instances. The numerical results show that our approach reduces the running times significantly in many cases. Extensions of this idea to other second-order 2-clubs will also be discussed.

#### 3 - Interdicting Low-diameter Clusters in Graphs

Hao Pan, Oklahoma State University, 4508 Aggie Drive, Stillwater, OK, 74074, United States, Juan Sebastian Borrero, Baski Balasundaram

A  $k$ -club, for a positive integer  $k$ , is a subset of vertices that induces a subgraph of diameter at most  $k$ . It is a clique relaxation that can be used to model low-diameter clusters in graph-based data mining. The  $k$ -clubs have been used to detect cohesive subgroups in social networks and functional modules in protein interaction networks. In this talk, we will consider an interdiction counterpart: given a graph  $G$  and a positive integer  $b$ , the  $k$ -club interdiction problem is to find a vertex subset  $S$  of size at most  $b$  such that the maximum  $k$ -club in  $G-S$  is minimized. We will discuss formulation and solution techniques for this min-max problem and discuss our preliminary findings in solving the problem when  $k = 2$ .

#### 4 - An Integer Programming Framework for Identifying Duplicate Network Personas

Sean Suehr, North Carolina Agricultural and Technical State University, 1601 E. Market Street, Greensboro, NC, 27411, United States, Chrysafis Vogiatzis

In this talk, we present an integer programming framework at the intersection of social network analysis and law enforcement intelligence that can identify persons of interest. Criminal networks are complex due to the limited and imperfect information available and the fact that participating entities misrepresent themselves so as to stay hidden. We formally define this problem and derive its computational complexity. We finish the talk with results on the criminal network of 9/11. Our approach identifies two distinct clusters of criminals participating in two separate subplots.

## ■ SA08

North Bldg 124A

### Bilevel Models in Network Optimization

Sponsored: Optimization/Network Optimization

Sponsored Session

Chair: Colin P. Gillen, University of Pittsburgh, 1025 Benedum Hall, 3700 O'Hara Street, Pittsburgh, PA, 15261, United States

#### 1 - Sequential Shortest Path Interdiction with Incomplete Information and Limited Feedback

Jing Yang, University of Pittsburgh, United States, Juan Sebastian Borrero, Oleg A. Prokopyev, Denis Saure

We study a sequential interdiction problem where the interdictor has partial information about the network. At each period, interdictor blocks at most  $k$  arcs to maximize evader's cost and then evader traverses the shortest path from two fixed nodes in the remaining graph. The interdictor doesn't know real cost, and at

each time she only observes the total cost of the path traversed by the evader. We propose GRN policy and investigate its properties as well as necessity. Moreover, we show that convergence to the optimal solution takes a worst-case exponential time. In this sense, we consider different versions of imperfect and randomized feedback, and prove worst-case polynomial convergence bounds.

#### 2 - On Bilevel Minimum and Bottleneck Spanning Tree Problems

Xueyu Shi, University of Pittsburgh, 1, Pittsburgh, PA, United States, Bo Zeng, Oleg A. Prokopyev

We study a class of bilevel spanning tree problems (BSTs) that involve two independent decision-makers (DMs), who jointly construct a spanning tree in a graph. One DM firstly selects a subset of edges from the set under her control. The other then completes the spanning tree construction using the edges selected. We study BSTs with the sum- and bottleneck-type objective functions for the two DMs. The polynomial-time algorithms are proposed in both optimistic and pessimistic settings for BSTs where at least one of the DMs has the bottleneck-type objective. For BST with the sum-type objectives for two DMs, we provide an equivalent single-level linear mixed-integer programming formulation.

#### 3 - Minimum Cost Edge Blocker Clique Problem

Foad Mahdavi Pajouh, University of Massachusetts-Boston, 100 Morrissey Boulevard, Boston, MA, 02125-3393, United States

The minimum cost edge blocker clique problem (EBCP) is introduced as the problem of blocking a minimum cost subset of edges in a graph so that each clique's weight is bounded above by some threshold. Large-weight cliques effectively model clusters of important actors with quick communications in real-world settings such as social, communication, and biological systems. This talk presents complexity results, polyhedral results, and two exact algorithms for this problem. Computational results of solving EBCP on a collection of random graphs and power-law real-world networks by using our proposed exact algorithms are also provided.

#### 4 - Critical Elements for Network Cascade Control

Colin P. Gillen, University of Pittsburgh, 1025 Benedum Hall, 3700 O'Hara Street, Pittsburgh, PA, 15261, United States, Alexander Veremyev, Oleg A. Prokopyev, Eduardo Pasillao

Network cascades represent a number of real-life applications: social influence, electrical grid failures, viral spread, and so on. The commonality between these phenomena is that they begin from a set of seed nodes and spread to other regions of the network. We consider a robust critical elements detection problem where the decision-maker wishes to control the spread of cascading behavior via node threshold modification (within a budget). The arc weights - how much influence one node has on another - are uncertain. The solution approaches include robust mixed-integer programming and centrality-based heuristics. Extensive computational experiments demonstrate the value of these methods.

## ■ SA09

North Bldg 124B

### Advances in First-Order Methods

Sponsored: Optimization/Nonlinear Programming

Sponsored Session

Chair: Angelia Nedich, ASU, Tempe, AZ, 85281, United States

#### 1 - A Push-pull Gradient Method for Distributed Optimization in Networks

Shi Pu, ASU, Tempe, AZ, 85281, United States, Angelia Nedich

We consider a new gradient-based method for distributed optimization in a directed network, where each agent has its own convex cost function and the goal is to minimize the sum of the functions. Each node maintains two estimates, namely, an estimate of the optimal decision variable and an estimate of the average gradient of the cost functions. From the viewpoint of an agent, the information about the decision variable (resp. gradients) is pushed to (resp. pulled from) the neighbors. The method unifies the algorithms with different distributed architecture, including decentralized and centralized ones. We show the algorithm converges linearly for strongly convex and smooth objective functions.

#### 2 - A Dual Approach for Optimal Algorithms in Distributed Optimization Over Networks

Cesar A. Uribe, University of Illinois at Urbana-Champaign, Urbana, IL, 61801, United States, Soomin Lee, Alexander Gasnikov, Angelia Nedich

We study the optimal convergence rates for distributed convex optimization problems over networks, where the objective is to minimize the sum of local functions of the nodes in the network. We provide complexity bounds for four cases: each function is strongly convex and smooth, when it is either strongly convex or smooth, and when it is convex but neither strongly convex nor smooth. Our approach is based on the dual problem and includes the graph that models the communication restrictions. We show distributed algorithms with the same optimal rates as their centralized counterparts (up to logarithmic factors), with an additional cost related to the communication graph.



### 3 - Using Second-order Information to Accelerate Incremental Gradient Methods

Hoi-To Wai, Arizona State University, Tempe, AZ, United States,  
Wei Shi, Cesar A. Uribe, Angelia Nedich, Anna Scaglione

Finite sum problems arise in applications of machine learning and control systems. To handle them, one may apply incremental method that divides the objective into chunks, processed one-at-a-time. Existing methods suffer from slow convergence limited by number of chunks involved. This talk introduces a curvature aided technique for incremental gradient methods. We propose a CIAG method using the technique and show that its asymptotic convergence rate is independent of the number of chunks. Two extensions are discussed: Nesterov acceleration is applied and an accelerated rate can be achieved; for distributed optimization, we use a random-walk based method with a rate robust to graph topology.

### 4 - Projective Splitting with Forward Steps: Asynchronous and Block-iterative Operator Splitting

Patrick Johnstone, Rutgers, 100 Rockefeller Rd., Piscataway, NJ, 08854, United States, Jonathan Eckstein

For a recently proposed projective splitting framework, we show how to replace the fundamental subproblem calculation using a backward step with one based on two forward steps. The resulting algorithms have the same kind of coordination procedure and can be implemented in the same block-iterative, distributed, and asynchronous manner, but may perform backward steps on some operators and forward steps on others. Prior algorithms in the projective splitting family have used only backward steps. Forward steps can be used for Lipschitz-continuous operators if the stepsize is bounded by the inverse of the Lipschitz constant, or if a backtracking procedure is used. We also derive convergence rates.

## SA10

North Bldg 125A

### Joint Session MSOM/Practice Curated: Empirical and Analytical Research to Improve Humanitarian Service Delivery

Sponsored: Manufacturing & Service Oper Mgmt

Sponsored Session

Chair: Mahyar Eftekhari, Arizona State University, Tempe, AZ, 85287, United States

#### 1 - What Drives Humanitarian Organizations' Donation Income? An Empirical Investigation

Iman Parsa, Arizona State University, Mahyar Eftekhari,  
Charles J. Corbett

For their survival, humanitarian organizations greatly depend on donations they receive. We empirically study how different factors impact individual donations and government grants that medium and large humanitarian organizations receive to see whether, and how, they can adopt policies to attract more donations. These factors include elements related to organizations' internal operations, such as program spending ratio and transparency, as well as external factors, like media exposure.

#### 2 - A Field Study of Charitable Giving Reveals that Reciprocity Decays over Time

Amanda Chuan, University of Pennsylvania, Philadelphia, PA, United States, Judd Kessler, Katherine Milkman

We examine how reciprocity changes over time using a large field study. We analyze data from a hospital system on 18,000 donation requests to former patients in the four months following their first hospital visit. We exploit quasi-experimental variation in solicitation timing and find that an extra 30-day delay between the provision of medical care and a donation solicitation decreases the likelihood of a donation by 30%. Our findings have important implications for models of economic behavior, which currently fail to incorporate reciprocity's sensitivity to time. The fact that reciprocal behavior decays rapidly also suggests the importance of capitalizing quickly on quid pro quo opportunities.

#### 3 - Communities in the Crossfire: How Companies Can Do Well by Doing Good

Andres Fernando Jola-Sanchez, Texas A&M University,  
College Station, TX, United States, Alfonso J. Pedraza-Martinez

We study how social investments in conflict zones affect firms' operational performance. Social investments can improve the well-being of communities in war-torn areas, but how do firms benefit from making these investments? We collect data from all the oil firms in Colombia and examine a law that compelled a group of these firms to spend 1% of their budget on social investments—the Colombian civil war is rampant in oil regions. We find this group obtains higher operating margins compared to the group the law did not affect. By influencing workforce, sourcing and logistics processes, social investments reduce the frequency of disruptions affecting firms in conflict zones.

### 4 - Supply Management for Rapid-onset Disasters: Effects of Supply, Demand, and Budget Uncertainty

Mahyar Eftekhari, Arizona State University, BA 433, Main Campus,  
P.O. Box 874706, Tempe, AZ, 85287, United States, Jing-Sheng  
Jeannette Song, Scott Webster

To fulfill beneficiaries' demands, humanitarian organizations should design a cost-efficient and time-effective procurement policy. We consider and analyze two common supply management policies: pre-positioning and local-purchasing. Our analysis takes demand, supply, and budget uncertainties into account.

### 5 - Do Optimization Models for Humanitarian Operations Need a Paradigm Shift

Harwin de Vries, INSEAD, Boulevard de Constance, Fontainebleau,  
77210, France, Luk N. Van Wassenhove

Optimization approaches for planning and routing of humanitarian field operations have been studied a lot. Yet, their adoption in practice seems absent. Based on interviews, literature, and modeling results, we discuss the applicability and cost-effectiveness of such approaches and identify areas where future research is needed.

## SA11

North Bldg 125B

### Supply Chain Finance/Risk Management

Sponsored: Manufacturing & Service Oper Mgmt/IFORM

Sponsored Session

Chair: Heikki Peura, Imperial College Business School, London, SW7 2AZ, United Kingdom

#### 1 - Trade Credit Provision and Inventory Performance

Christopher J. Chen, London Business School, London Business  
School, Regent's Park, London, NW14SA, United Kingdom,  
Nitish Jain, S. Alex Yang

Long payment terms in the form of trade credit are believed to be harmful to suppliers and was a driving force behind French regulation in 2008 limiting its duration. Using data on European retailers, we exploit variation in firms' exposure to the law in order to quantify its impact on trade credit usage. Leveraging this natural experiment further, we test theories on the relationship between trade credit and operational decisions.

#### 2 - Supplier Diversification Under Buyer Risk

Nikos Trichakis, MIT, Jiri Chod, Gerry Tsoukalas

When should a firm diversify its supply base? Most extant theories attribute supplier diversification to supplier risk. We develop a new theory that attributes diversification to buyer risk. When suppliers are subject to buyer default risk, buyers may take costly action to signal creditworthiness so as to obtain more favorable terms. But once signaling costs are sunk, buyers sourcing from a single supplier become vulnerable to future holdup. Although ex ante supply base diversification can be effective at alleviating this problem, we show that it comes at the expense of higher upfront signaling costs. We resolve the ensuing trade-off and show that diversification emerges as the preferred strategy.

#### 3 - The Value of Supply Chain Disruption Duration Information

Bill Schmidt, Cornell University, Ithaca, NY, United States,  
Mili Mehrotra

Using the supply chain and production data from a multinational division of a Fortune 500 manufacturing firm, we quantify the operational performance impact of disruption duration information. We identify several factors that influence the value of information, helping the firm to eliminate anywhere from less than 1% to as much as 100% of the cost of the disruption.

## ■ SA12

North Bldg 126A

### Joint Session OR Frontiers/Practice Curated: Novel Applications of Operations Research

Emerging Topic: OR Frontiers

Emerging Topic Session

Chair: Srinivas Bollapragada, GE Global Research Center,  
Niskayuna, NY, 12309, United States

#### 1 - Optimal Scheduling of Field Resources for Power Plant Outages

Rajeev Namboothiri, GE Global Research, John F. Welch  
Technology Centre, Plot # 122, EPIP Phase 2., Bangalore, 560066,  
India, Srinivas Bollapragada, Babu Narayanan, Guillaume Camard,  
Ahmed Khattab

Power plants around the world require field resources to carry out maintenance outages. A host of complex constraints restrict the eligibility and availability of a field resource to perform a maintenance task. We developed a Field Resource Scheduling algorithm minimizing the total cost associated with field services while meeting all the real-world constraints. Using exhaustive preprocessing, an intelligently designed cost function, and a novel approach that iteratively solves a series of linear programs, we achieve the optimal solution within a few minutes. GE Power has been using this tool in the Middle East Africa region, resulting in operational cost savings of millions of dollars.

#### 2 - Optimizing Maintenance Operations at GE Wind Sites

Rajesh Tyagi, GE Global Research Center, 1 Research Circle,  
Niskayuna, NY, 12309, United States, Nitish Umang

GE Renewable, a leading producer of wind turbines, also sells service agreements to guarantee their operating availability at wind sites. These sites have up to 200 turbines, with outstanding maintenance work for a subset of turbines at any given time. We present a Digital Plan of the Day (DPOD) system that has been developed to optimize the maintenance operations to determine which turbines will have maintenance performed that day and develops a schedule for each crew. DPOD has so far been implemented at over 50 wind farms in North America.

#### 3 - Rail Network Operations Optimization

Srinivas Bollapragada, Chief Scientist, GE Global Research Center,  
1 Research Circle, K1-4A50A, Niskayuna, NY, 12309, United States

Each of the seven major railroads (called Class 1 railroads) in North America owns over 20,000 miles of track and runs over 1000 trains per day. Moving freight on such complex networks requires meticulous planning and execution. Multiple opportunities exist to realize large savings from improving railroad operations. For example, increasing the average speed of freight trains by one mile per hour saves a Class 1 railroad around \$200 million per year. Improving terminal (rail yard) operations and decreasing fuel consumed by locomotives also result in similar sized savings. We will describe some of our work on developing algorithms to improve operations of rail networks.

#### 4 - Rail Network Operations Optimization

Srinivas Bollapragada, PhD, Chief Scientist, GE Global Research  
Center, Niskayuna, NY, USA.

Each of the seven major railroads (called Class 1 railroads) in North America owns over 20,000 miles of track and runs over 1000 trains per day. Moving freight on such complex networks requires meticulous planning and execution. Multiple opportunities exist to realize large savings from improving railroad operations. For example, increasing the average speed of freight trains by one mile per hour saves a Class 1 railroad around \$200 million per year. Improving terminal (rail yard) operations and decreasing fuel consumed by locomotives also result in similar sized savings. We will describe some of our work on developing algorithms to improve operations of rail networks.

## ■ SA13

North Bldg 126B

### Hospital Operations

Sponsored: Manufacturing & Service Oper Mgmt/Healthcare  
Operations

Sponsored Session

Chair: Anita L. Tucker, Boston University, Boston, MA, 02215,  
United States

#### 1 - Gatekeeping Under Congestion: An Empirical Study of Referral Errors in the Emergency Department

Michael Freeman, INSEAD, 1 Ayer Rajah Avenue, Singapore  
138676, Singapore, Stefan Scholtes, Susan Robinson

Using data from an ED, we study the effect of congestion on the accuracy of gatekeeping decisions (hospital admission or discharge home) and the effectiveness of a second gatekeeping stage (a clinical decision unit) in reducing

errors. We find that when congestion increases, physicians prevent an increase in wrongful discharges by lowering the threshold for hospital admission. This leads to a surge in avoidable hospitalizations and creates "false demand for hospital beds when ED physicians should be protecting this constrained resource. Introducing a second gatekeeping stage - to which physicians can pass patients if they are unable to make an accurate referral decision - can mitigate this effect.

#### 2 - Inpatient Overflow: An Approximate Dynamic Programming Approach

Pengyi Shi, Purdue University, 403 W. State St, Krannert School of  
Management, Kran 472, West Lafayette, IN, 47907, United States,  
Jim Dai

Due to the inherent variations in arrivals and discharges, hospital managers may assign a patient to a non-primary inpatient ward, especially when the patient has boarded in the Emergency Department (ED) for several hours. Such overflow practice helps alleviate ward congestion but may compromise quality of care. We formulate this overflow decision problem as a Markov decision process (MDP) within a multi-class, multi-pool queueing network setting. To overcome the curse-of-dimensionality, we develop an approximate dynamic programming (ADP) algorithm, where we use a novel combination of a fluid control model and an integrated single-pool model to guide the choice of the basis functions.

#### 3 - Impact of Health Information Technology Enabled Coordination on Inpatient Length of Stay

Temidayo Adepoju, Boston University, Boston, MA, 02215, United  
States, Helen Jin, Anita Tucker, Rebecca Lara, Chris Manasseh

Preparing patients for discharge is a complex process that involves the aggregate effort of multiple care providers. We examine how health IT-enabled coordination in discharge process can improve inpatient length of stay (LOS) through the use of an electronic tool called a pre-discharge order (PDO). A pre-discharge order is a tool in the EHR to facilitate discharge process. When completed, it appears as an electronic signal in a patient's chart to alert care providers of any discharge barriers a patient may have. We find that inpatient LOS is reduced when discharge process is coordinated using the pre-discharge order, particularly for patients with complex discharge placement.

#### 4 - Capacity Pooling in Hospitals: The Hidden Consequences of Off-service Placement

Hummy Song, The Wharton School, University of Pennsylvania,  
Philadelphia, PA, United States, Anita L. Tucker, Ryan Graue,  
Sarah Moravick, Julius J. Yang

Given a highly variable patient census at the service level yet a fixed allocation of inpatient beds to services, a significant portion of admitted patients become "off-service" patients. These patients are physically located in a bed that belongs to a different service (e.g., general surgery) while still being cared for by a physician of the service (e.g., cardiac medicine). We examine the tradeoffs and consequences of assigning incoming patients to an off-service bed as opposed to an on-service bed.

## ■ SA14

North Bldg 126C

### Innovative Service Models

Sponsored: Manufacturing & Service Oper Mgmt/Service  
Operations

Sponsored Session

Chair: Guillaume Roels, INSEAD, Fontainebleau, 77305, France

#### 1 - Information, Subsidies or Surge? An Experimental Approach to Drivers Relocation

Guangwen Kong, MN, United States, Yinghao Zhang,  
Zhongzhong Jiang

Relocating drivers to different geographical regions to reduce the mismatch between the demand and supply is important for on-demand ride hailing platform. We consider a variety of policies to incentivize drivers for relocation, including sharing information about supply and demand, suggestions for relocation, relocation cost subsidies, surge pricing, and their combinations. We examine the effectiveness of those policies to relocate drivers in a series of controlled lab experiments.

#### 2 - Examining Links Between Service Design and Customer Performance in High Anxiety Settings

Michelle A. Shell, Harvard Business School, 1 Upland Woods  
Circle, Unit 406, Norwood, MA, 02062, United States, Ryan Buell

Many service settings are rife with anxiety, yet the impact of anxiety on service relationships is not well understood, nor is it often factored into service design. Through a series of lab and field experiments, conducted in the high-anxiety domain of financial services, we document the negative effects of anxiety on customer performance. We further demonstrate how providing customers with access to human contact when they're feeling anxious can improve customers' willingness to engage, elevate their satisfaction with their own decisions, and engender greater trust in the company.

### 3 - Optimal Practice Processes for Performance

Guillaume Roels, INSEAD, Boulevard de Constance,  
Fontainebleau, 77305, France

Throughout their lifetime, people engage in many activities to learn new skills or develop their abilities. Although endurance sports training, motor learning, and cognitive learning have their own idiosyncrasies, they can all be viewed as processes of repeated practice to increase performance. Yet, there exist few guidelines to optimize such processes. Building upon research in endurance sports training and learning, this paper proposes a behavioral model of a practice process and optimizes it to maximize performance on a predefined date. We demonstrate the optimality of distributing practice over time, of tapering, and of periodization.

### 4 - Quality and Product Cycles in Fast Fashion

Xiaoyang Long, University of Wisconsin-Madison, Wisconsin  
School of Business, 975 University Avenue, Madison, WI, 53706,  
United States, Javad Nasiry

A “fast fashion business model allows firms to react quickly to changing consumer trends by introducing new products. We study the effect of this business model on a firm’s new product introduction frequency and product quality decisions when consumer taste changes over multiple periods.

## ■ SA15

North Bldg 127A

### Appointment and Capacity Planning in Health Care

Sponsored: Manufacturing & Service Oper Mgmt/Service  
Operations

Sponsored Session

Chair: Itai Gurvich, Cornell University, New York, NY, 10044,  
United States

Co-Chair: Benjamin Grant, Kellogg School of Management,  
Evanston, IL, 60201, United States

#### 1 - Managing Appointment Booking Under Customer Choices

Nan Liu, Boston College, 140 Commonwealth Avenue, Fulton  
Hall, Room 340, Chestnut Hill, MA, 02467, United States,  
Peter Van de Ven, Bo Zhang

Motivated by the increasing use of online appointment booking platforms, we study how to offer appointment slots to customers in order to maximize the total number of slots booked. We develop two models, non-sequential offering and sequential offering, to capture different types of interactions between customers and the scheduling system. In these two models, the scheduler offers either a single set of appointment slots for the arriving customer to choose from, or multiple sets in sequence, respectively. Given the ongoing growth of online and mobile appointment booking platforms, our research findings can inform user interface design of these booking platforms.

#### 2 - The Zocdoc Effect: How Does Online Information Impact Appointment Availability in Outpatient Care?

Yuqian Xu, University of Illinois at Urbana-Champaign, Wohlers  
Hall 487, 1206 S. 6th St, Champaign, IL, 61820, United States,  
Mor Armony

In this paper, we propose a queueing model to study the impact of online information on doctor’s service decisions. We characterize the equilibrium strategy of the doctor, and show the impact of market size on the equilibrium strategy.

#### 3 - Optimal Dynamic Appointment Scheduling of Base and Surge Capacity

Benjamin Grant, Kellogg School of Management, 1881 Oak  
Avenue, # 1307W, Evanston, IL, 60201, United States,  
Itai Gurvich, Jan A. Van Mieghem, R. Kannan Mutharasan

We study dynamic stochastic appointment scheduling when delaying appointments increases the risk of incurring costly failures, such as readmissions in health care or engine failures in preventative maintenance. When near-term base appointment capacity is full, the scheduler faces a trade-off between delaying an appointment at the risk of costly failures versus the additional cost of scheduling the appointment sooner using surge capacity.

## ■ SA16

North Bldg 127B

### Electricity Demand Side Management

Sponsored: Manufacturing & Service Oper Mgmt/Sustainable  
Operations

Sponsored Session

Chair: Ali Fattahi, University of California-Los Angeles, Los Angeles,  
CA, 90095, United States

#### 1 - Demand Response Planner for Building Districts

Juan Alejandro Gomez-Herrera, Polytechnique Montreal,  
Montreal, QC, Canada, Miguel F. Anjos, Luce Brotcorne

We present a demand response planner for a district with heterogeneous buildings. This approach allows to aggregate a large number of end-users by identifying and selecting power capacity profiles. The user engagement combined with storage and local generation resources allows to provide demand response services to the grid operator. We use a multi-objective optimization model to trade off the total cost of energy consumption and the user’s dissatisfaction generated by load shifting. Computational experiments validate the performance of the proposed approach.

#### 2 - A Computational General Equilibrium Model for Power Interruption Contracts

Lakshmi Palaparambil Dinesh, Purdue Fort Wayne, Fort Wayne,  
IN, United States

Demand Response (DR) is reduces consumer electricity bills and energy consumption. There are several models incorporating DR technology into customer bill reduction models. Our model focuses on large scale mixed integer linear programming. In this paper, we plan to look at a DR customer bill reduction when there are back up storage devices such as batteries or solar photovoltaic cells available to the customer. We explore three possible scenarios (i) Does the customer bill reduce further when there are batteries/solar as well as DR? (ii) If there is a reduction, how sizable is that reduction? (iii) How do the solution times change when back up storage is included in the model?

#### 3 - That’s Not Fair: Tariff Structures for Electricity Markets with Rooftop Solar

Siddharth Prakash Singh, Carnegie Mellon University, Tepper  
School of Business, 5000 Forbes Avenue, Pittsburgh, PA, 15213,  
United States, Alan Scheller-Wolf

Increased penetration of rooftop solar has led to decreased utility profitability and undesirable cross-subsidization among customers. Regulatory responses have been controversial; changes in Nevada induced SolarCity, the market leader in solar systems, to suspend operations. We show analytically that for a regulator to induce a socially desirable outcome, two tariff features are essential — the ability to discriminate among customer tiers and the ability to discriminate between solar and non-solar customers. We present a tariff, featuring full retail price repurchasing from residential solar customers with these features. We use data from Nevada and New Mexico to illustrate our findings.

#### 4 - An Analysis of Demand Response Programs in the Wholesale Electricity Market

Asligul Serasu Duran, Haskayne School of Business, University of  
Calgary, Calgary, AB, Canada, Baris Ata, Ozge Islegen

We build a model to explore the participation and the compensation of demand response (DR) providers in the wholesale electricity market, motivated by the Federal Energy Regulatory Commission’s (FERC) order that authorized DR resources to receive the same market clearing prices that generating resources receive. We consider alternative compensation schemes for DR providers, and explore the changes in the investment decisions, electricity prices, generators and DR providers’ profits, and consumer welfare.

#### 5 - Peak Load Energy Management by Direct Load Control Contracts

Ali Fattahi, University of California-Los Angeles, Anderson School  
of Management, B501, Los Angeles, CA, 90095, United States,  
Sriram Dasu, Reza Ahmadi

We study peak load energy management by direct load control contracts (DLCCs) that utilities use to curtail electricity consumption of the participating customers during peak load periods. These contracts stipulate a limit on the number of times (calls) and the total number of hours of power reduction per customer as well as the duration of each call. This is a provably difficult (NP-hard) optimization problem. We develop an approximation scheme and analyze its asymptotic behavior. We show that the relative error approaches zero as problem size (length of the horizon) approaches infinity. We apply our solution approach to the data provided by three major utility companies in California.



## ■ SA17

North Bldg 127C

**Additive Manufacturing and Innovation in a Supply Chain**Sponsored: Manufacturing & Service Oper Mgmt/Supply Chain  
Sponsored Session

Chair: Jayashankar M. Swaminathan, University of North Carolina-Chapel Hill, Chapel Hill, NC, 27599-3490, United States

Co-Chair: Ali Kemal Parlakturk, University of North Carolina Kenan-Flagler, Chapel Hill, NC, 27599-3490, United States

**1 - Retailing with 3D Printing**

Yao Cui, Cornell University, 401N Sage Hall, Ithaca, NY, 14853, United States, Li Chen, Hau Leung Lee

In this paper, we study the impact of adopting 3D printing in a dual-channel (i.e., online and in-store) retail setting, on a firm's product offering and pricing decisions for the two channels, as well as supply chain operations.

**2 - Decentralized Customization with 3D Printing: Drivers of Retail Level 3D Printing**

Nagarajan Sethuraman, UNC Chapel Hill, Chapel Hill, NC, 27514, United States, Ali Kemal Parlakturk, Jayashankar M. Swaminathan

In this paper, we study the trade-offs involved in decentralized customization enabled by 3D printing at retail stores. We develop an analytical model that considers in-store 3D printing as a component of the firm's broader product line strategy. Managerial insights from our novel model can guide the adoption of 3D printing at retail stores.

**3 - Product Management and Innovation in a Supply Chain**

Hyoduk Shin, Junghee Lee, Vish Krishnan

In a technology-intensive supply chains, intellectual property invented by an upstream firm must be embedded in a manufactured subsystem which is then integrated into a full system sold to end consumers. Upstream technology providers face key business model decisions about how to monetize their innovation, which is the focus on this study. They typically employ a royalty-driven business model, but the royalty-based approach has gotten complicated in industrial multi-lateral supply chains. We consider these business model decisions in the context of the industry structure of the subsystem and full system markets.

**4 - Printing Spare Parts at Remote Locations. Fulfilling the Promise of Additive Manufacturing**

Rob Basten, Associate Professor, Eindhoven University of Technology, Eindhoven, Netherlands, Bram Westerweel, Geert-Jan Van Houtum

We investigate the benefits of on-site printing of spare parts at remote geographical locations. We consider a periodic-review inventory control system with two supply sources. Regular replenishments occur according to a fixed interval. In between replenishments, spare parts can be printed that possess a lower reliability than regular parts. We characterize the optimal inventory control policy and conduct experiments to investigate the benefits of on-site printing. Using case studies with the Royal Netherlands Army we show that simple AM technology can create significant benefits. Our results show that remote locations are a prime candidate for implementing AM technology to print spare parts.

## ■ SA18

North Bldg 128A

**New Problems in Supply Chain**Sponsored: Manufacturing & Service Oper Mgmt/Supply Chain  
Sponsored Session

Chair: Georgia Perakis, Massachusetts Institute of Technology, Cambridge, MA

**1 - Value of Failure Prediction Models for Efficient Network Inspection Operations**

Mathieu Dahan, Massachusetts Institute of Technology, 77 Massachusetts Avenue, Room 1-253c, Cambridge, MA, 02139, United States, Steven B. Link, Saurabh Amin, Georgia Perakis

Can infrastructure utilities significantly improve their network inspection operations using predictive failure models? To address this question, we formulate a multi-stage stochastic problem for scheduling regions to visit and inspecting each region. The objective is to maximize failure localization performance under timing, sensing, and routing constraints. We apply techniques for solving submodular function optimization under matroid constraints, and evaluate the solution quality under offline prediction, dynamic customer calls, and strategic probing. We estimate the value of diagnostic information in these cases using data from SF Bay area's gas pipeline inspection operations.

**2 - Inducing Fresh Food Spending Through Optimal Incentives**

Elisabeth Paulson, MIT, Retsef Levi, Georgia Perakis

We consider a two-stage scenario where a planner first allocates a fixed budget across possible interventions, and the consumer then decides how to allocate his food budget between fresh food and other options. The goal of the planner is to maximize the consumer's spending on fresh food. We formulate this game as a two-stage optimization problem with equilibrium constraints, and consider both single-period and stationary multi-stage versions. We present structural results on the planner's optimal budget allocation, validate our results on a nationally representative data set, and compare these results to the current status quo of federal spending.

**3 - Pricing For Heterogeneous Products: Analytics for Tickets Reselling**

Rim Hariss, Massachusetts Institute of Technology, Operations Research Center, 1 Amherst Street, Cambridge, MA, 02142, United States, Max R. Biggs, Charles Herrmann, Michael Li, Georgia Perakis

In collaboration with a major secondary ticket exchange, we study a trading strategy for buying and reselling tickets for events. We look at classifying whether each individual ticket will sell at a given price, in the presence of confounding factors. We construct an optimization based ticket trading strategy that is the reseller is piloting as well as a novel method for heterogeneous treatment effect estimation for classification. On synthetic datasets this approach beats state-of-the-art machine learning approaches for estimating treatment effects. We show using our approach to trade on NBA ticket listings yields a seller's revenue up to \$9.6 million (27% return) for a single season.

**4 - Performance Guarantees for Revenue Maximization in Online Type Matching**

Elahleh Fata, Massachusetts Institute of Technology, 125 Massachusetts Avenue, Aeronautics and Astronautics, Cambridge, MA, 02139, United States, Will Ma, David Simchi-Levi

In today's online marketplaces, the problem of dynamically matching agents in real-time is becoming increasingly prevalent. It captures important tradeoffs faced by the emerging sharing economy, as well as classical inventory and production decisions faced by the transportation industries. The dynamic matching of agents is an inherently challenging task due to the uncertainty in the future agents' arrival. We consider this problem from the perspective of a central platform who, through historical data, has established the types of agents that could potentially arrive and the relationships between them. The platform's goal is to maximize the total reward earned by matching agents over time.

## ■ SA19

North Bldg 128B

**Platform Ecosystem Management**Sponsored: Revenue Management & Pricing  
Sponsored Session

Chair: Hemant K. Bhargava, University of California, Davis, CA, 95616, United States

Co-Chair: Ramnik Arora, Facebook, Menlo Park, CA, 9, United States

**1 - Salesforce Incentives for Selling Platforms**

Hemant K. Bhargava, University of California, Gh-3108, Graduate School of Management, Davis, CA, 95616, United States, Olivier J. Rubel

We present a model of salesforce incentives for selling platforms, considering both direct and cross-market network effects, which distort the traditional tensions inherent in designing salesforce compensation plans.

**2 - Impact of Platform Venture Capital Investments on the Entry and Exit of Complementary Applications in Ecosystems**

Arvind Karunakaran, McGill University, Montreal, QC, H3H 2P2, Canada, Joey Van Angeren

We examine how platform venture capital (PVC) investments affect the entry and exit of complementary applications. We hypothesize that complementors are more likely to introduce and less likely to retract apps in their market niche following a PVC investment. We test this using data collected from a B2B platform.

**3 - Economic Analysis of Peer-to-peer Insurance**

Hong Guo, University of Notre Dame, 356 Mendoza College Of Business, University of Notre Dame, Notre Dame, IN, 46556-5646, United States, Yu-Chen Yang, Yong Jin

Peer-to-peer (P2P) insurance is an emerging form of insurance contract enabled by InsurTech advancements. Building upon classic principal-agent model with moral hazard, this paper studies the key characteristics of P2P insurance as a form of insurance contract and compares it to traditional insurance contracts. We identify conditions under which P2P insurance alleviates moral hazard and evaluate its efficiency.

#### 4 - Formal Barriers to Proof of Stake Protocols

Christos-Alexandros Psomas, Carnegie Mellon University, PA,  
United States, Jonah Brown-Cohen, Arvind Narayanan,  
Seth Matthew Weinberg

The security of most existing cryptocurrencies is based on a concept called Proof of Work, in which users must solve a computationally hard cryptopuzzle to authorize transactions ("one unit of computation, one vote"). Proof of Stake is an alternative concept that instead selects users to authorize transactions proportional to their wealth ("one coin, one vote"). In this work we focus on incentive-driven deviations (participants deviate if doing so yields higher reward) instead of adversarial corruption (an adversary controls part of the network, but everyone else is honest) and show several formal barriers to designing incentive-compatible PoS cryptocurrencies.

### ■ SA20

North Bldg 129A

#### Data Driven Models for Revenue Management and Pricing in Industry

Sponsored: Revenue Management & Pricing

Sponsored Session

Chair: Ravi Kumar, PROS, Inc. World Headquarters, Houston, TX

##### 1 - Methods of Handling Flexible Capacity in Hotel Revenue Management

Matthew Maxwell, SAS Institute, Inc., 500 SAS Campus Drive,  
Cary, NC, 27513, United States

One of the fundamental assumptions of revenue management is that capacity is fixed. In some situations this restriction is relaxed by using one type of capacity to fulfill requests for a different type of capacity. The most common practice of this concept is upgrading where a request for a lower class of capacity is satisfied by a higher class of capacity. An alternate form of flexible capacity is that of component rooms, or virtual suites. In this scenario, a set of rooms can either be closed off and sold as separate individual units or combined and sold as a larger, more valuable suite. We explore methods for handling this type of flexible capacity.

##### 2 - Reinforcement Learning for Revenue Management and Pricing

Manu Chaudhary, PROS, Houston, TX, 77054, United States,  
Warren Scott

We discuss two algorithms to automatically and dynamically generate optimal prices for non-negotiated settings. For the first algorithm, dynamic pricing problem is posed as a Multi Armed bandit problem and is solved using Beta-Bernoulli-Thompson Sampling (TS). The second algorithm is based on more traditional approach of calculating demand response models but the optimization method considers confidence intervals around mean demand to reduce risk. We compare the performance of these algorithms using simulations.

##### 3 - Flexible Products in Air Cargo Revenue Management

Dirk Daniel Sierag, PROS, Houston, TX, United States

Air Cargo is a highly volatile business, especially regarding uncertainty in the volume and weight of the shipments and capacity of the plane. Moreover, a full flight often consists of only a small number of shipments. We propose a revenue optimization model that deals with the uncertainty in two ways: first, demand is modeled as flexible products; and second, a robust optimization approach is proposed.

##### 4 - Holistic Approach to Predicting the Wholesale Energy Market Prices

Bokan Chen, CA, United States, Ana Radovanovic, Tommaso Nesti

Electricity market price predictions enable energy market participants to shape their consumption or supply while meeting their economic and environmental objectives. By utilizing the basic properties of the supply-demand matching process performed by grid operators, we developed a method to recover energy market's structure and predict the resulting prices as a function of generation mix and system load on the grid. Our methodology uses the latest advancements in compressed sensing and statistics to cope with the highly dimensional and sparse real grid topology graphs, underlying physical laws, as well as scarce and public market data.

### ■ SA21

North Bldg 129B

#### Bridging Machine Learning and Revenue Management

Sponsored: Revenue Management & Pricing

Sponsored Session

Chair: Xi Chen, NYU Stern School of Business

##### 1 - Data Driven Algorithms for Assortment Planning Under Nested Logit Model

Yuan Zhou, Indiana University at Bloomington, Xi Chen,  
Yining Wang

Dynamic assortment planning concerns about the optimal displaying strategy to maximize total revenue over the selling season with no a priori information on consumers' choice model parameters. Combining combinatorial techniques and the powerful lower-upper confidence bound (LUCB) method, we develop data-driven algorithms to simultaneously learn consumers' model (the Nested Logit model) and optimize assortment selection decisions. Our algorithms' performance guarantees surprisingly do not depend on the number of candidate products, which is particularly useful in settings such as fast fashion retailing and online advertising.

##### 2 - Learning Preferences with Side-information: Near Optimal Recovery of Tensors

Andrew Li, MIT, Cambridge, MA, United States, Vivek Farias

Many recent problems in e-commerce can be cast as large-scale problems of tensor recovery. Thus motivated, we study the problem of recovering tensors from their noisy observations. We provide an efficient algorithm to recover structurally simple tensors given noisy observations of their entries; our version of simplicity subsumes low rank tensors for various definitions of tensor rank. Our algorithm is practical for massive datasets and provides a significant performance improvement over incumbent approaches to Tensor recovery. Further, we show a near-optimal recovery guarantee. Experiments on music streaming data demonstrate the performance and scalability of our algorithm.

##### 3 - Attribute Based Dynamic Learning Approach to Assortment Selection

Avadhanula Vashist, Columbia University, Shipra Agrawal,  
Vineet Goyal, Assaf Zeevi

We consider an online assortment optimization problem, where in every round, the retailer offers an assortment of  $N$  substitutable products to a consumer, and observes the consumers response. We assume that the products are described by a set of attributes and the mean utility of a product is linear in the values of attributes. We model consumer choice behavior using the widely used multinomial logit (MNL) model, and consider the retailer's problem of dynamically learning the model parameters, while optimizing cumulative revenues over the selling horizon  $T$ . We present an algorithm whose regret only depends on the number of attributes and is independent on the number of products.

##### 4 - Dynamic Assortment Selection with Features

Wang Yining, Carnegie Mellon University

We consider the problem of dynamic assortment planning with features. More specifically, each item is associated with a known revenue parameter and a known feature vector (which changes over time), and the customers' preferences are modeled by items' feature vectors together with an unknown linear model. We discuss intuitive policies for dynamic planning (i.e., learning preference models and maximize expected revenues at the same time) and give near-optimal regret analysis.

### ■ SA22

North Bldg 130

#### Joint Session RMP/Practice Curated: Interface between RM and Market Analytics

Sponsored: Revenue Management & Pricing

Sponsored Session

Chair: Ang Li, PROS, Inc., Houston, TX, 77002, United States

##### 1 - Spot Scheduling for Cable Networks

Xin Ma, Turner Broadcasting System, Inc., 1050 Techwood Dr NW,  
Atlanta, GA, 30318, United States, J. Antonio Carbajal

Spot scheduling is a media planning process in which TV commercials are placed into buckets of commercial airtime for airing. In this presentation, we provide some background information of media planning, and review different types of deals, constraints, and requirements involved in this process. Then we introduce the spot scheduling problem, and discuss how we decompose it in a multi-stage optimization framework that realizes spot prioritization and best use of Turner's commercial airtime.

## 2 - A Probabilistic Modeling Framework to Optimize Volume Pricing Settings

Jose Luis P. Arreola, Home Depot (Blacklocus), Austin, TX,  
United States, Joseph Nipko

We optimize volume pricing settings in terms of tier quantity ( $Q_i$ ) and discount ( $d_i$ ) over retail price in order to perform constrained optimization on performance metrics such as Margin, Revenue and Unit Sellthrough. Our inference approach is based on probabilistic modeling of the order size distribution of similar products, under an observed array of ( $Q_i$ ,  $d_i$ ) settings. Further, our methodology allows for the overlaying of product-specific context parameters in a modular way. We apply our approach to three different groups of construction material products and we conduct market price tests on them. We observe that our framework predicts directionally correct revenue and margin lift estimates.

## 3 - DP Based Efficient Frontier in Revenue Management

Wei Wang, PROS Inc, 3100 Main St, Suite #900, Houston, TX,  
77002, United States, Fangzhou Sun, Darius Walczak,  
Subhash C. Sarin

In this paper, we consider jointly optimizing expected profit contribution and resource utilization for revenue management problems. In particular we use a constrained Markov decision process-based approach to find the corresponding efficient frontier.

## 4 - Predicting Users' Forecast Influences via Machine Learning

Ang Li, PROS, Inc., 3100 Main Street, Suite #900, Houston, TX,  
77002, United States, Stephanie Zipkin

Airline RM analysts spend a significant amount of time monitoring and influencing forecasted demand. In this innovation study, we developed several supervised learning models to predict demand and influences based on historical data. In particular, we derived features which mimic a variety of influence criteria and rules the analysts apply through surveying domain experts. Our numerical experiments show that a medium-complexity decision tree model reliably predicts user influences with low error rate. We discuss how the RM system may be augmented with our model, and outline our next steps of study.

## SA23

North Bldg 131A

## Joint Session FSS/Practice Curated: Financial Engineering Applications

Sponsored: Finance

Sponsored Session

Chair: Justin Sirignano, University of Illinois at Urbana-Champaign,  
Irvine, CA, 92617, United States

Co-Chair: Alexandra Chronopoulou, University of Illinois,  
Urbana-Champaign, Urbana, IL

## 1 - Optimal Kernel Estimation of Spot Volatility of Stochastic Differential Equations

Jose E. Figueroa-Lopez, Washington University-St Louis, One  
Brookings Drive, St Louis, MO, 63130, United States

A feasible method of bandwidth and kernel selection for spot volatility kernel estimators is proposed, under some mild conditions on the volatility process, which not only cover classical Brownian motion driven dynamics but also some processes driven by long-memory fractional Brownian motions. The optimal selection of the kernel function is also investigated. For Brownian Motion type volatilities, the optimal kernel turns out to be an exponential function, while, for fractional Brownian motion type volatilities, numerical results to compute the optimal kernel are devised. Simulation studies further confirm the good performance of the proposed methods. This is based on joint work with Cheng Li.

## 2 - Delta-hedging in Fractional Volatility Models

Alexandra Chronopoulou, University of Illinois, Urbana-Champaign,  
104 South Mathews Avenue, 117 Transportation Building, Urbana, IL, 61801, United States, Qi Zhao

In this talk, we propose a delta-hedging strategy for a long memory stochastic volatility model (LMSV). This is a model in which the volatility is driven by a fractional Ornstein-Uhlenbeck process with long-memory parameter  $H$ . We compute the so-called hedging bias, i.e. the difference between the Black-Scholes delta and the LMSV delta as a function of  $H$ , and we determine when a European-type option is over-hedged or under-hedged. Finally, we apply our approach to SP 500 data.

## 3 - Mean Field Analysis of Neural Networks in Machine Learning

Alexandra Chronopoulou, University of Illinois, Urbana-Champaign,  
104 South Mathews Avenue, 117 Transportation Building, Urbana, IL, 61801, United States, Justin Sirignano,  
University of Illinois at Urbana-Champaign, Irvine, CA, USA.

Neural network models in machine learning have revolutionized fields such as image, text, and speech recognition. There's also growing interest in using neural

networks for applications in science, engineering, medicine, and finance. Despite their immense success in practice, there is limited mathematical understanding of neural networks. We mathematically study neural networks in the asymptotic regime of simultaneously (A) large network sizes and (B) large numbers of stochastic gradient descent training iterations. We rigorously prove that the neural network satisfies a Law of Large Numbers (LLN) and a Central Limit Theorem (CLT). The LLN is the solution of a nonlinear partial differential equation while the CLT satisfies a stochastic partial differential equation.

## 4 - Deep Learning in Asset Pricing

Markus Pelger, Stanford University, 312 Huang Engineering  
Center, 475 Via Ortega, Stanford, CA, 94305, United States

We estimate a general non-linear asset pricing model and optimal portfolios with a deep-neural network applied to all U.S. equity data combined with all relevant macroeconomic and firm-specific information. No-Arbitrage Pricing theory implies that the conditional expectation of the discounted excess returns are zero under the risk-neutral probability. Our data-driven approach estimates the stochastic discount factor that explains all asset prices from this basic assumption. Our model allows us to identify the key factors for asset prices, find mis-pricing of stocks and generate the optimal portfolio with the highest Sharpe ratio.

## SA24

North Bldg 131B

## E-Business

Sponsored: EBusiness

Sponsored Session

Chair: Gulver Karamemis, University of Rhode Island, Kingston, RI,  
02881, United States

## 1 - Beauty Contest and Social Value of Fintech: An Economic Analysis

Anurag Garg, University of Florida, Gainesville, FL, 32603,  
United States, Liangfei Qiu, Subhrajyoti Bandyopadhyay

With the advance of Fintech, traders in financial markets use the information available on social media to gauge investor sentiment and form higher order beliefs. Following the insight of Keynes (1936) on beauty contest, we develop an analytical model to analyze how higher order beliefs, driven by the Fintech revolution, affect market efficiency. We find that higher order beliefs tend to reduce market efficiency because public information is over weighted. Since accounting disclosure is a main source of public information, our results highlight that the optimal level of accounting disclosure (transparency) can be dramatically affected by the use of Fintech in financial trading.

## 2 - Clustering of Heterogeneous Retailers at Heterogeneous Locations

Hong Guo, University of Notre Dame, 356 Mendoza College Of  
Business, University of Notre Dame, Notre Dame, IN, 46556-5646,  
United States, Chao Ding, Xuying Zhao,  
Jing-Sheng Jeannette Song

In this paper, we investigate the clustering phenomenon of heterogeneous retailers at heterogeneous locations. Specifically, we develop a game theoretical model to analyze mainstream and niche retailers' incentives to locate close to each other and their choices between central and peripheral locations.

## 3 - An Empirical Investigation of Online Crowd-funding Performance

Lina Zhou, University of North Carolina-Charlotte, Charlotte, NC,  
USA, Kexin Zhao, Anamika Paul, Xia Zhao

Online crowdfunding is an emerging platform that facilitates raising money for a for-profit or non-profit project from a large number of people. The determinants of online crowdfunding performance may depend on the type of a project. We conducted an empirical investigation of one type of crowdfunding project to gain insights into its performance.

## 4 - Search Engine Advertising; Optimal Contractual Strategies Between Firms and Their Affiliates

Siddharth Bhattacharya, Fox School of Business, Temple  
University, Alter Hall, 1801 Liacouras Walk, Philadelphia, PA,  
19122, United States, Subodha Kumar, Sunil Wattal

Firms increasingly utilize third party affiliates to advertise on their behalf. The focus of our research is to find what optimal pricing and advertising strategies between firms and affiliates maximize profits and how does product quality, customer heterogeneity, affiliate type and type of ad contract (with Google) affect those strategies.



## ■ SA25

North Bldg 131C

### Best Cluster Paper – I

Sponsored: Service Science

Sponsored Session

Chair: Paul R. Messinger, University of Alberta, Edmonton, AB, T6G 2R6, Canada

#### 1 - Service Science Best Cluster Paper

Paul R. Messinger, University of Alberta, University of Alberta, Edmonton, AB, T6G 2R6, Canada

This session consists of finalists presentations (judged by an expert panel) to determine the Service Science Section Best Cluster Paper.

## ■ SA26

North Bldg 132A

### Approximations and Controls of Queues

Sponsored: Applied Probability

Sponsored Session

Chair: Yunan Liu, NCSU

#### 1 - Staffing and Scheduling to Differentiate Service Levels in Multiclass Overloaded Queues with Time-varying Arrivals

Xu Sun, Columbia University, Kyle Hovey, Yunan Liu

Motivated by large-scale service systems (e.g., emergency departments), we study an overloaded multi-class queueing system having time-varying arrivals. Our objective is to devise appropriate staffing and scheduling policies to achieve differentiated service levels for each customer class. Our proposed policy is both time dependent (coping with the time variability in arrival pattern) and state dependent (capturing the stochastic variability in service times and arrival times). Effectiveness of our staffing and scheduling rules are confirmed by heavy traffic limit theorems (with the system scale increases) and computer simulation experiments.

#### 2 - Many Server Scaling of the N-system Under FCFS-LISF

Dongyuan Zhan, University College London, Gideon Weiss

The N-System with independent Poisson arrivals and exponential server-dependent service times under first come first served and assign to longest idle server policy has explicit steady state distribution. We scale the arrival and the number of servers simultaneously, and obtain the fluid and central limit approximation for the steady state. This is the first step towards exploring the many server scaling limit behavior of general parallel service systems.

#### 3 - On the Stability of Large-scale Markovian Parallel Server Networks

Guodong Pang, PhD, Penn State University

We will discuss stability of Markov parallel server networks with/without abandonment in the Halfin-Whitt regime. In particular, exponential ergodicity properties are presented for both the limiting controlled diffusions and the diffusion-scaled queueing processes under various scheduling policies.

#### 4 - State Dependent Pricing in Naor Model with Arrival Rate Uncertainty

Chengcheng Liu, The University of Texas at Austin, Austin, TX, United States, John Hasenbein

This paper examines extensions of Naor's observable queueing model in which arrival rate is not known with certainty by either customers or system managers. We consider the arrival rate as a non-degenerate random variable with unknown realizations. This work is also an extension of the study of Chen and Hasenbein on a related model in that their model only considers homogeneous customer populations. In view of a social optimizer (SO) and a revenue maximizer (RM), we analyze the social benefit rate and revenue rate, and investigate optimal state-dependent pricing policies in the presence of arrival rate uncertainty.

#### 5 - On Brownian Approximation for Superposition of Renewal Processes

Shuangchi He, National University of Singapore, 1 Engineering Drive 2, Dept. of Industrial and Systems Engineering, Singapore, 117576, Singapore

We investigate the superposition of many stationary renewal processes. A centered and scaled version of this superposition process is known to weakly converge to a Gaussian process, which is in general not a Brownian motion. By an expansion of the covariance function, we discuss when the superposition process can be accurately approximated by a Brownian motion. We also discuss an application to many-server queues with a general service time distribution in the efficiency-driven regime.

## ■ SA28

North Bldg 221A

### Joint Session MSOM/APS: Supply Chain Management: Pricing, Shipping, and Expansion

Sponsored: Manufacturing & Service Oper Mgmt

Sponsored Session

Chair: Nan Yang, University of Miami, Coral Gables, FL, 33146, United States

Co-Chair: Panos Kouvelis, Washington University in St. Louis, One Brookings Drive, Campus Box 1156, Saint Louis, MO, 63130-4899, United States

#### 1 - Shipping Consolidation Across Two Warehouses with Delivery Deadline and Expedited Options for E-commerce and Omni-channel Retailers

Lai Wei, University of Michigan, Ann Arbor, MI, United States, Stefanus Jasin, Roman Kapuscinski

Shipment consolidation is commonly used to avoid some of the shipping costs. However, when pending current orders are consolidated with future orders it may require more expensive expedited shipment to meet shorter deadlines. In this paper, we study the optimal consolidation policy focusing on the trade-off between economies of scale and expedited shipping cost. The optimal policies and their structures are characterized, where the impact of expedited shipment on both shipping policy and order fulfillment policy are explored. Two easily implementable heuristics are proposed, which perform within 1-2% of the optimal in intensive numerical tests.

#### 2 - Joint Pricing and Inventory Optimization Under Minimax Regret

Chengzhang Li, Purdue University, West Lafayette, IN, United States, Qi Feng, Mengshi Lu

We study a robust pricing newsvendor problem under the min-max regret framework where the firm only knows the interval in which the random factor lies with high confidence in the demand model. We characterize the optimal decisions with a general demand model and further study the impact of inventory risk by comparing the optimal price and the risk-free price. We also study comparative statics of the optimal price with different unit cost and degree of demand ambiguity. Finally, our approach outperforms the traditional one in a data-driven setting with small sample sizes, high demand variability, or demand model misspecification.

#### 3 - Supply Chain Competition: A Market Game Approach

C Gizem Korpeoglu, University College London, Gower Street, London, WC1E 6BT, United Kingdom, Ersin Korpeoglu, Soo-Haeng Cho

We study expansion and integration of supply chains where multiple suppliers sell to multiple retailers through a wholesale market. While the prior literature fails to capture retailers' influence on the wholesale price, we develop a novel model based on a market-game mechanism that captures it. We show that more retailers raise the wholesale price and improve retailer profits, and hence the supply chain expansion is more beneficial than the prior literature finds. We then analyze integration of local supply chains, and find that this integration raises the total profit of all firms, but may reduce the total profit of firms in a retailer-oriented local supply chain with more retailers than suppliers.

#### 4 - Impact of Price Postponement and Risk Aversion Under Supply Random Yield

Panos Kouvelis, Washington University in St. Louis, One Brookings Drive, Campus Box 1156, Saint Louis, MO, 63130-4899, United States, Guang Xiao, Nan Yang

In this paper, we investigate the impact of price postponement and risk aversion under supply yield risk. More specifically, we study a risk averse monopoly firm's production and pricing decisions under supply random yield with two distinct pricing schemes: ex ante pricing and responsive pricing. We adopt the conditional-value-at-risk (CVaR) as the risk aversion measurement, and investigate the impact of the firm's risk aversion level on its optimal decisions and the corresponding profit.

## ■ SA29

North Bldg 221B

### Joint Session TSL/Urb/Practice Curated: Activity Modeling and Applications in Urban Transport

Sponsored: TSL/Urban Transportation

Sponsored Session

Chair: Jee Eun Kang, University at Buffalo, Buffalo, NY, 14260, United States

#### 1 - Strategic Public Parking Locations with Routing Considerations of Individual Autonomous Vehicles

Somayeh Dejbord, University at Buffalo, Tonawanda, NY, United States

Use of personal Autonomous vehicles (AV) will lead to increased Vehicle-Miles-Traveled (VMT) particularly due to empty trips. While a decision maker makes the parking location decision (public), the decision of using the parking is made by individual private AV owners, households. A location siting model uses flow-based demand data as an input but the actual decision of using parking is made individually with finer details such as what household members' daily itineraries are. We develop a methodology to approximate input data for the location model using data available to the decision maker.

#### 2 - Integrating Augmented Reality, Gamification and Social Interactions in Mobile Apps to Influence Short- and Long-term Travel Decisions

Yuntao Guo, Purdue University, West Lafayette, IN, United States, Srinivas Peeta, Shubham Agrawal, Irina Benedyk, Mohammad Miralinaghi

This study develops a framework that integrates augmented reality (AR), gamification and social interactions through mobile apps to influence short- and long-term travel decisions by using a popular location-based AR gaming app, Pok mon GO, as a case study. A survey was designed and implemented to evaluate impacts of the integrated mobile apps on travel decisions using participants with different levels of familiarity and experience with Pok mon GO. Descriptive statistics and econometric model estimation results illustrate that such integrated mobile apps can be leveraged for implementing behavioral intervention strategies to influence travel decisions of subpopulations of travelers.

#### 3 - Household Activity and Travel Patterns with Shared Autonomous Vehicles

Marjan Mosslemi, University of California-Irvine, Irvine, CA, United States, R. Jayakrishnan

Access to shared autonomous vehicles can create new opportunities for performing daily activities and will change traveler behavior. We explore the potential impacts by modifying the constraints of the Household Activity Pattern Problem (HAPP). The new constraints include two new specifications of the supply environment (shared mobility and driverless vehicles) and reflect following new opportunities: more vehicle resources than personal vehicles, possibility to perform activities in-vehicle, some activities that can travel.

## ■ SA30

North Bldg 221C

### Where To Next? Dynamic Fleet Optimization for Urban Transportation

Sponsored: TSL/Urban Transportation

Sponsored Session

Chair: Konstantina Mellou, Massachusetts Institute of Technology, Cambridge, MA, 02141, United States

#### 1 - Dynamically Route Deviation and Fair Cost Allocation for a Flexible Transit Service

Saeid Rasulkhani, New York University, Brooklyn, NY, 11209, United States, Joseph Y. J. Chow

In this study we are extending conventional MAST system which is a flexible transit system that a vehicle can deviate from its fixed path to pick up or drop off passengers. Unlike conventional MAST system, passengers may need to walk a block or so to be served rather than in their request point. Moreover, a fair cost allocation based on concept of Shapley Value from cooperative game, divides cost of deviation between served users.

#### 2 - Routing the Boston School Buses

Sebastien Martin, Massachusetts Institute of Technology, Cambridge, MA, 02139, United States, Dimitris Bertsimas, Arthur J. Delarue

In this talk, we focus on the major problem of school transportation, as part of a collaboration with Boston Public Schools (BPS). School transportation involves delivering students to school every morning and back home every afternoon

using a fleet of specialized vehicles (around 700 hundred school buses for Boston), we identify a multistage decomposition of the problem and propose integer programming formulations and efficient heuristics for each stage, improving on the state of the art. We also highlight interesting aspects of a collaboration with a public organization. This work allowed the city of Boston to save a yearly 4+ million dollars starting in 2017-18, reinvested in education.

#### 3 - Stable Matching in Large Scale Ridesharing Systems

Amir Tafreshian, University of Michigan Ann Arbor, 2350 Hayward St., 1430 Gg Brown Bldg., Civil And Environmental Engineering, Ann Arbor, MI, United States, Neda Masoud

Ride-sharing systems require an effective and efficient optimization methodology to match drivers and riders in large-scale transportation networks. This matching problem can be modeled as an assignment game in a 2-sided market. The core of this game provides a set of stable matchings between riders and drivers. However, the solutions in this set are not equivalent from the perspective of different participants in the system. This paper proposes a framework to establish stable matches in a 2-sided market while considering a secondary objective function on the optimal payoffs.

#### 4 - Dynamic Redistribution of Bike Sharing Systems

Konstantina Mellou, Massachusetts Institute of Technology, Cambridge, MA, 02141, United States, Patrick Jaillet

This talk focuses on the redistribution of bike sharing systems. Spatial and temporal imbalances of the user demand often lead to empty and full bike stations. Since reliable service is essential for the viability of these systems, operators use a fleet of vehicles to redistribute bikes across the network. We propose a mixed integer programming formulation for the dynamic version of the problem, and, combined with heuristics and decomposition techniques, we are able to solve large real-world instances. Since accurate estimation of the user demand is essential to plan for efficient rebalancing, we also develop approaches to consider lost and shifted demand, which very often are not taken into account.

## ■ SA32

North Bldg 222B

### Joint Session TSL/ICS: Approximate Dynamic Programming and Reinforcement Learning for Routing I

Sponsored: TSL/Freight Transportation & Logistics

Sponsored Session

Chair: Dirk C. Mattfeld, University of Braunschweig, Braunschweig, 38106, Germany

#### 1 - Approximate Dynamic Programming for Planning Driverless Fleets of Electric Vehicles

Lina Al-Kanj, Princeton University, Warren B. Powell

The combination of a centrally managed fleet of driverless vehicles, along with the operating characteristics of electric vehicles, is creating a transformative new technology that offers significant cost savings. This problem involves a control problem for assigning requesters to cars, a planning problem for deciding on the fleet size and a pricing problem all of which are high dimensional stochastic dynamic programs. We use approximate dynamic programming to develop high-quality operational control strategies which are then used to determine the optimal fleet size. We also discuss surge pricing to smooth out daily peaks using an optimal learning approach in a real-time setting.

#### 2 - Policy Search for Bike Sharing Systems

Dirk C. Mattfeld, University of Braunschweig, Wirtschaftsinformatik, Braunschweig, 38106, Germany, Jan Brinkmann, Marlin Ulmer

We present the stochastic-dynamic inventory routing problem for bike sharing systems (SDIRP). The objective of the SDIRP is to avoid unsatisfied demand by dynamically relocating bikes during the day. To anticipate potential future demands in the current inventory decisions, we present a dynamic lookahead policy (DLA). The policy simulates future demand over a predefined horizon. Because the demand patterns change over the course of the day, the DLA horizons are time-dependent and autonomously parametrized by means of value function approximation, a method of approximate dynamic programming. We compare the DLA with conventional relocation strategies from the literature and lookahead policies with static horizons. Our study based on real-world data by the BSS of Minneapolis (Minnesota, USA) reveals the benefits of both anticipation by lookahead as well as the time-dependent horizons of the DLA. We additionally show how the DLA is able to autonomously adapt to the demand patterns.

### 3 - Route-based Approximate Dynamic Programming for Demand Management in Attended Home Delivery

Sebastian Koch, University of Augsburg, Universitätsstrasse 16, Augsburg, 86159, Germany, Robert Klein

Attended home delivery describes the delivery of goods or services to a customer at an appointed time, often called the service time window, in order to avoid failure of delivery. In this talk, we re-consider the problem of integrated dynamic pricing for demand management regarding the customers' time window choices and the subsequent operational vehicle routing. Thereby, we propose a novel approximate dynamic programming approach, anticipating the future value of the demand management decisions based on temporal features from dynamically generated route plans. In a simulation study, we compare our approach with state-of-the-art benchmarks, showing its profit potential.

### 4 - Restoration of Disrupted Services Through Reinforcement Learning

Aybike Ulsan, Northeastern University, Boston, MA, United States, Ozlem Ergun

In the case of a disruptive event, the roads of a transportation network may be blocked with debris. Thus, many emergency response operations are hampered. In order to build a post-disruption resiliency, connectivity between supply and demand points within the service network should be maintained by effective clearance of the debris. We tackle this problem (road network recovery problem) with stochastic demands. We model this problem as MDP and develop a framework to aid the scheduling of road clearance decisions by modeling and simulating an intelligent clearance agent through reinforcement learning. Then, we use a linear function approximation to generate policies for large-sized instances.

## SA33

North Bldg 222C

### Disaster and Humanitarian Logistics

Sponsored: Transportation Science & Logistics

Sponsored Session

Chair: Zhijie Dong, Texas State University, San Marcos, TX, 78640, United States

#### 1 - Hospital Coordination Strategies for Managing Emergency Patients in Disaster

Elise Miller-Hooks, Professor, George Mason University, 208 Rosalie Cove Ct, Silver Spring, MD, 20905, United States, Bahar Shahverdi, Mersedeh Tariverdi

A discrete event simulation framework is presented for assessing the benefits of coordinated response of hospitals in a disaster incident involving area-wide damage and mass casualties. Impacts on critical resources, physical spaces and demand are modeled. Findings from numerical experiments on a case study involving multiple hospitals spaced over a large metropolitan region show the potential of strategies involving resource sharing and joint capacity enhancement alternatives.

#### 2 - Pre-positioning of Relief Supplies and Supplier Selection in Humanitarian Relief

Zhijie Dong, Texas State University, RFM 4227B, 601 University Drive, San Marcos, TX, 78640, United States

This paper integrates supplier selection into the pre-positioning of relief supplies. The supplier selection criteria include price discounts offered by suppliers based on order quantity and required lead time as well as suppliers' own physical inventories. By considering failure risks, this paper presents a two-stage stochastic programming model to produce plans including facility location and inventory, supplier selection, and distribution of relief supplies. A case study focused on hurricane threat in the Gulf Coast area of the US illustrates application of the model. Sensitivity analysis of comparison experiments offers managerial insights for relief agencies.

#### 3 - A Dynamic Team Orienteering Model of Dynamic Urban Search and Rescue Deployment Decision-making with Social Data Inputs

Erin Mullin, University of Arkansas, Walnut Creek, CA, 94596, United States, Ashlea Bennett Milburn

Deployment decisions for urban search and rescue (USAR) teams are critical in saving as many lives as possible. One challenge is having accurate information regarding the locations and needs of disaster survivors. Another is the simultaneous consideration of multiple inputs and constraints in a highly dynamic and uncertain environment. This research addresses these challenges by permitting social data during deployment planning and by modeling the USAR deployment problem as a dynamic variant of the team orienteering problem with time windows. A first-come-first-served strategy, often employed in practice, is compared with an optimal offline approach for a small set of test instances.

### 4 - A Generalized Routing and Accessibility Analysis System for Flooding: Iowa Testbed

Peng Chen, The University of Iowa, Ann Melissa Campbell, Ibrahim Demir

In this study, a generalized routing and accessibility analysis system is developed for flooding events. The system helps people find alternative routes and understand which areas in the disaster zone have limited travel accessibility. Our system can support emergency response activities with a real-time and dynamic routing framework for evacuation, rescuing civilians, delivering supplies, and deciding emergency center placement.

## SA34

North Bldg 223

### 8:00 - 8:45 AnyLogic /8:45 - 9:30 Uber

Vendor Workshop Session

#### 1- AnyLogic: The Most Comprehensive Simulation Modeling Platform for Business and Research

Rainer Dronzek, AnyLogic North America, Chicago, IL, United States, Arash Mahdavi

In this tutorial, we will discuss how you can leverage unique features of AnyLogic simulation software and AnyLogic Cloud to solve your business challenges or perform scientific research. We demonstrate application of simulation in various domains and demonstrate state-of-the-art technologies that can take your simulation models to the next level in terms of sophistication and usefulness.

#### 2 - Marketplace Optimization and Data Science at Uber

Hamid Nazerzadeh, UBER & University of Southern California, Bridge Memorial Hall - BRI 401B, 3670 Trousdale Parkway, Los Angeles, CA, 90089, United States

Marketplace is the center of Uber's business, where riders and drivers come together at extraordinary scale. The data science team tackles problems such as optimizing Uber's short and long term pricing mechanisms; efficiently matching incoming trip requests in Uber's dispatch system; developing innovative incentive schemes that reward riders and drivers for choosing our network; and providing optimal routes and positioning suggestions to save time for everybody. In this presentation, we discuss in more details some of these challenging and innovative projects.

## SA35

North Bldg 224A

### Joint Session AAS/TSL-Air: Passenger Flow Forecasting and Airport Operations

Sponsored: Aviation Applications

Sponsored Session

Chair: Heng Chen, University of Nebraska-Lincoln, Lincoln, NE, 68588, United States

#### 1 - Forecasting Airport Transfer Passenger Flow Using Machine Learning and Real-time Data

Xiaoja Guo, PhD Student, University College London, International Hall, Lansdowne Terrace, London, WC1N 1AS, United Kingdom, Yael S. Grushka-Cockayne, Bert De Reyck

Air passengers missing their connection can have a major impact on satisfaction and airline delays. Accurate forecasts of the flow of passengers and their journey times through an airport can help improve the experience of connecting passengers and support airline, airport, and air space punctuality. In collaboration with Heathrow Airport, we utilize real-time data to develop a predictive system based on a regression tree and Copula-based simulations. These real-time predictions can be used to inform target off-block time adjustments and determine resourcing levels at security and immigration.

#### 2 - Runway Scheduling Under Winter Conditions

Maximilian Pohl, Technical University of Munich, Munich, Germany, Rainer Kolisch

We address the runway scheduling problem under consideration of winter operations. During periods of snowfall, runways have to be intermittently closed in order to clear them from snow, ice and slush. We propose an integrated discrete optimization model to simultaneously plan snow removal for multiple runways and to assign runways and starting and landing times to aircraft. To improve the computation times of our model formulation, problem specific pruning rules and valid inequalities are presented. We also discuss a method to derive initial start solutions heuristically. The model is tested and validated with real-world data from Munich International Airport.



### 3 - Optimal Gate Assignment Under the Consideration of Airport Retailing

Tulay Flamand, Colorado School of Mines, Division of Economics and Business, Engineering Hall 816 15th Street, Room 313, Golden, CO, 80401, United States, Heng Chen

We address a gate assignment problem and its impact on airport retail sales. We develop a mixed-integer programming model that assigns flights to gates in a way that optimizes several objectives, as well as the retail sales. A column generation methodology is used to solve this challenging problem and the results of the computational study are reported.

### 4 - A Variable Neighborhood Search Approach for the Flight-to-gate Reassignment Problem

Moschoula Pternea, University of Maryland, College Park, MD, 20740, United States, Ali Haghani

The reallocation of flights to gates in case of schedule disruptions is a key airport recovery operation. Especially in hub airports, disruptions affect connecting passengers by causing failed connections or lost baggage. At the same time, introducing passenger transfers in mathematical programming models makes the problem intractable. In this context, we develop a Variable Neighborhood Search approach to generate near-optimal solutions with the objective to minimize additional schedule disturbances, as well as passenger and baggage misconnections. Our preliminary experiments indicate that our metaheuristic approach shows promising results in terms of both solution quality and time.

## ■ SA36

North Bldg 224B

### Airline Recovery Operations and Route Planning

Sponsored: Aviation Applications

Sponsored Session

Chair: Vikrant Vaze, Dartmouth College, Hanover, NH, 03755, United States

#### 1 - An Integrated Model for Airline Operations Recovery: Emphasizing Passenger Compensation Impacts

Luis Cadarso, Rey Juan Carlos University, Camino del Molino s/n, Fuenlabrada, 28943, Spain, Vikrant Vaze

The European flight delay compensation regulation (EC) No 261/2004 establishes common rules on compensation to passengers in the event of disruptions. We develop an integrated approach that recovers airline timetable, fleet assignment, aircraft routings, and passenger itineraries capturing the impacts of airlines' decisions on passenger compensation. We evaluate scenarios involving disruptions, and optimize recovery decisions to maximize profits by modeling passenger no-shows after disruptions.

#### 2 - Fleet Operations - Combining Tail Assignment and Schedule Recovery

Andreas Westerlund, Jeppesen, Odinsgatan 9, Gothenburg, 411 03, Sweden, Mattias Gronkvist

Tail assignment is the process of planning the assignment of aircraft to flights from the day of operations and a few days, or weeks, into the future. Schedule recovery is the process of deciding how to operate the aircraft at an airline when operational disruptions happen. In this presentation we will discuss how a combined tail assignment system and schedule recovery system gives benefits compared to using separate systems. We will also show how integration with crew tracking and flight planning can give additional benefits. Computational results on real-world data will be presented.

#### 3 - A Two Stage Route Planning Algorithm for Light Aircraft Transportation Systems

Shadi Sharif Azadeh, Assistant Professor, Erasmus University Rotterdam, Burgemeester Oudlaan 50, Rotterdam, 3062 PA, Netherlands

This paper presents a route planning algorithm for light aircraft operating system under visual flight rules. The problem aims to find a minimum duration, collision free route in three spatial dimensions. The calculated route takes into account the aircraft kinodynamic characteristics and its interaction with external wind. A data processing approach is presented to recast the flying environment as a series of polyhedrons based on which a mixed integer linear model is formulated. A two stage route planning heuristic is developed to solve real life instances. Computational experiments depict the efficiency of this approach.

## ■ SA37

North Bldg 225A

### Information and Dynamic Decision Making

Sponsored: Applied Probability

Sponsored Session

Chair: Kuang Xu, Stanford Graduate School of Business, Stanford, CA

#### 1 - Privacy and Incentives in Dynamic Games

Rachel Cummings, Georgia Tech, 755 Ferst Drive NW, Atlanta, GA, 30332-0205, United States

When strategic agents play repeated games against the same opponents, they may be concerned about information leakage across rounds. Examples include repeated posted pricing and repeated auctions, where a seller can learn a buyer's value to charge higher prices in future rounds. In this talk, we will explore differential privacy as a tool for mitigating these incentive issues and bringing behavior in each round closer to that of the stage game.

#### 2 - Satisficing in Time-sensitive Bandit Learning

Daniel Russo, Columbia University, New York, NY, United States, Benjamin Van Roy

Much of the recent literature on bandit learning focuses on algorithms that aim to converge on an optimal action. One shortcoming is that this orientation does not account for time sensitivity, which can play a crucial role when learning an optimal action requires much more information than near-optimal ones. We consider instead learning a satisficing action, which is near-optimal while requiring less information, and propose satisficing Thompson sampling, an algorithm that serves this purpose. We establish a general bound on expected discounted regret and discuss relations with the theory of rate distortion, which offers guidance on the selection of satisficing actions.

#### 3 - Capacity of Resource Allocation Under Information Loss

Yuan Zhong, Booth School of Business, University of Chicago, Kuang Xu

We consider the problem of dynamic resource allocation under information loss, in general stochastic processing systems. Information loss is modeled as an information channel. We characterize the capacity region under various channel models, and analyze the role of memory in policy design.

## ■ SA38

North Bldg 225B

### Applied Probability in Machine Learning and Optimization II

Sponsored: Applied Probability

Sponsored Session

Chair: Chang-Han Rhee, Centrum Wiskunde and Informatica, Amsterdam, 1018 MZ, Netherlands

#### 1 - Optimal Sampling Algorithms for Empirical Risk Minimization

Harsha Honnappa, Purdue University, 315 N. Grant Street, West Lafayette, IN, 47906, United States, Raghu Pasupathy, Prateek Jaiswal

We present a large deviations analysis of sample average approximation (SAA), specifically focused on empirical risk minimization (ERM) problems relevant to machine learning and M-estimation. We focus on situations where it is feasible to sample independently and without replacement at predefined grid-points in the design space. The resulting LD rate function is then used to extract a computational-effort allocation algorithm, that efficiently trades-off computational-effort against statistical accuracy. We prove the asymptotic consistency and efficiency of the resulting estimators.

#### 2 - Infinitely Many Armed Bandit Problem with Learned Rewards

Yang Cao, University of Southern California, Los Angeles, CA, United States

There are infinitely many arms with arm  $i$ ,  $i=1$  having value  $v_i$  where  $v_i$  are the values of i.i.d non-negative random variables following a known distribution  $F$ . The values  $v_i$  are initially unknown to the player, and will be learned once being played. In each game the player can choose either an observed arm or a new arm to play, and will receive a reward equal to the chosen arm's value. The objective is to find a policy that maximizes the expected sum of the rewards in  $N$  games. We show that the optimal policy is a threshold stopping policy when  $N$  is deterministic or a random variable having increasing failure rate. We also propose heuristic policies for the case when  $N$  has a general distribution.

### 3 - Testing Safety of Autonomous Vehicles Using Data-driven Rare-event Simulation

Hongseok Namkoong, Stanford University, Stanford, CA, 94305, United States

Despite recent progress in autonomous vehicles (AVs), rigorous tests are yet to be designed. Viewing this as a data-driven rare-event simulation problem, we first study a stylized i.i.d. random walk setting and give finite-sample minimax bounds and asymptotic rates for estimating the large deviation rate from data. Then, we implement a simulation framework (pseudo-reality) which can test the deep-learning based perception and control pipeline as a whole system. Use a learned behavior of environmental agents as our underlying model, we demonstrate our framework on a highway driving scenario, and show that rare-event simulation techniques can accelerate AV system evaluation.

### 4 - Ranking and Selection with High Dimensional Covariates

Xiaocheng Li, Stanford University, Stanford, CA, United States, Zeyu Zheng

Ranking and selection is concerned with making the best selection among many alternatives, whose unknown performances can be learned via sampling. Examples include selecting medicine and treatment regimes in healthcare systems and selecting online advertisements targeting Internet users. In this talk, we consider the settings in which the mean performance of each alternative depends on some observable high dimensional random covariates, where existing methods may become inefficient and even inapplicable. Our procedure effectively incorporate machine learning tools such as regularization and variable selection. Certain statistical guarantee is established under moderate assumptions.

## ■ SA39

North Bldg 226A

### Inventory Control

Sponsored: Applied Probability

Sponsored Session

Chair: Eugene A. Feinberg, Stony Brook University, Stony Brook, NY, 11794-3600, United States

Co-Chair: Mark S. Squillante, IBM Thomas J. Watson Research Center, IBM Thomas J. Watson Research Center, Yorktown Heights, NY, 10598, United States

#### 1 - Asymptotic Optimality of Constant-order Policies in Joint Pricing and Inventory Control Models

Linwei Xin, University of Chicago, 5807 S. Woodlawn Avenue, Chicago, IL, 60637, United States, Xin Chen, Alexander Stolyar

We consider a joint pricing and inventory control problem with positive replenishment lead times. Although this problem has been extensively studied in the literature, the structure of the optimal policy remains poorly understood. In this work, we propose a class of so-called constant-order list-price policies. We prove that the best constant-order list-price policy is indeed asymptotically optimal as the lead time grows large, which is exactly the setting in which the problem becomes computationally intractable due to the curse of dimensionality. We also show that the best constant-order list-price policy can be computed effectively.

#### 2 - Optimize Inventory Freshness in Supply Chain

Zhengliang Xue, IBM T.J. Watson Research Center, Yorktown Heights, NY, 10598, United States, David D. Yao, Markus Ettl

This paper studies the management of inventory freshness and optimization of the local inventory policy for all the members in a decentralized supply chain. We approximate the expected profit by the closed-form solutions, and use them to study the efficiency and security for all the transactions of selling and buying the fresh products at different ages of the product life-cycle.

#### 3 - Equicontinuity Conditions for Markov Decision Processes with Application to Inventory Control

Eugene A. Feinberg, Stony Brook University, Department of Applied Mathematics, and Statistics, Stony Brook, NY, 11794-3600, United States, Pavlo O. Kasyanov, Yan Liang

This talk discusses the equicontinuity condition and its generalization, the lower semi-equicontinuity condition, for Markov decision processes with average costs per unit time. These conditions imply the validity of average-cost optimality equations, convergence of discounted-cost relative value functions to average-cost value functions, and continuity properties of average-cost value functions. Periodic-review stochastic inventory models typically satisfy these conditions. This implies the validity of average-cost optimality equations for inventory models with average cost criteria and provides useful tools to derive structural properties of average-cost optimal policies.

### 4 - Stochastic Setup Cost Inventory Model with Backorders and Quasiconvex Cost Functions

Yan Liang, Stony Brook University, A-149, Math Tower, Stony Brook, NY, 11794, United States, Eugene A. Feinberg

This talk is concerned with a periodic-review setup-cost inventory model with backorders and holding/backlog costs satisfying quasiconvexity assumptions. We show that this model satisfies assumptions that imply the validity of optimality equations for discounted and average-cost criteria and the family of discounted relative value functions is equicontinuous. We establish two groups of results: (i) optimality of (s,S) policies for infinite-horizon problems under discounted and average-cost criteria, and (ii) convergence of optimal discounted lower thresholds and discounted relative value functions to their average-cost counterparts as the discount factor converges to 1.

## ■ SA40

North Bldg 226B

### Spatial Queueing and Matching Systems

Sponsored: Applied Probability

Sponsored Session

Chair: Varun Gupta, The University of Chicago Booth School of Business, Chicago, Illinois

Co-Chair: Ankur Mani, University of Minnesota, Minneapolis, MN

#### 1 - Pooling Policies in Ridesharing

Daniel Freund, Cornell University, 109 Lake St, Ithaca, NY, 14850, United States, Siddhartha Banerjee, Varun Gupta, Samitha Samaranayake

The ascent of ride-sharing platforms like Lyft, Didi, and Uber triggered a line of research investigating queueing-theoretic models of such systems. The fundamental matching task of interest in this area is to match drivers and passengers. In this work, we take that analysis one step further to analyze shared-ride modes like Lyft Line. For these settings we need to not only match drivers and passengers, but also match passengers with each other. We propose several (asymptotically optimal) policies of interest and discuss their tradeoffs in non-asymptotic regimes.

#### 2 - Matching Users Online: Balancing Matching Cost and Waiting Cost

Sai Sandeep, CMU, Pittsburgh, PA, United States, Varun Gupta, Ravishankar Krishnaswamy

In ride sharing platforms, the primary goal is to match drivers with riders to ensure that riders are paired to nearby drivers without waiting too long. This gives rise to an optimization problem where requests of two types arrive online, and the objective is to pair requests of different types so as to minimize sum of matching cost, and waiting cost. In this project, we consider this problem and its variant, also known as Min-Cost Perfect Matching with Delay (MPMD), survey the existing results and present new algorithms.

#### 3 - Matrix Geometric Analysis of Polling Queues in Series

Ravi Suman, University of Wisconsin-Madison, Madison, WI, 53726, United States, Ananth Krishnamurthy

We analyze a network of queues where the customers are served at each station in a fixed cyclic exhaustive manner. Under Markovian assumptions for arrival and service times, we conduct an exact analysis using matrix geometric approach. Exact solutions for queue length distributions and mean waiting times are determined and the effect of buffer sizes on performance measures are explored.

#### 4 - Walking vs. Waiting: Trade-offs when Pooling Resources Serving a Large Area

Daniel F. Silva, Auburn University, 3301 Shelby Center, Auburn, AL, 36849, United States, Mathias A. Klapp

We study the trade-offs between travel time and queue time in a two dimensional area, where stations are spatially separated. Customer demand appears randomly in a designated area, then each customer walks to a station to get service and then either walks to an exit or back to where they began. Examples include stadium concessions; department store check-outs; bars in a night club. We make assumptions about demand distribution, potential station locations and user preferences, then attempt to optimize a user utility function, subject to a budget on the available stations and servers.

#### 5 - A Spatial Queueing Model for Evaluating Feasibility of Last-mile On-demand Public Transportation Service

Alexander Vinel, Auburn University, 2479 Churchill Cir, Auburn, AL, 36832, United States, Daniel F. Silva

We consider modeling approaches for analysis of last-mile on-demand public transportation service. Specifically, we are interested in enabling evaluation of whether specific demand profiles and other system parameters allow for efficient implementation of such a service. We develop a series of models employing spatially and temporally distributed queueing systems. We will present some analytical conclusions as well as simulation results.

## ■ SA41

North Bldg 226C

**Joint Session DAS/Practice Curated:  
Risk and Decision Analytics**

Sponsored: Decision Analysis

Sponsored Session

Chair: Sayanti Mukhopadhyay, PhD, Purdue University, West Lafayette, IN, 47907, United States

**1 - Optimizing Inspection Routes in Pipe Networks**

Thomas Ying-Jeh Chen, University of Michigan, Ann Arbor, MI, 48105, United States, Connor Riley, Pascal Van Hentenryck, Seth Guikema

The inspection of aging water distribution pipes is a vital process for utilities to aid better decision making for risk-based management. To facilitate cost-efficient deployment of inspection robotics, a process that finds high risk pipe while accounting for the tool limitations is needed. We formulate the problem as an integer program, and explore a variety of methods to identify optimal routes: branch and bound, constraint generation, breadth-first search, depth-first search, and depth-first search with pruning. While only three factors are used to characterize tool limitations, the formulation can be extended to include technology-specific complexities in real world applications.

**2 - Optimizing Design for Hybrid Renewable Energy Systems Under Long-range Uncertainties**

Ramin Giah, Iowa State University, Ames, IA, 50010, United States

Understanding the potential for new applications and different environments under which a system will operate is important in engineering design. This presentation focuses on design with long-range uncertainty. We identify and model significant uncertainties that will impact the use and lifespan of a system. This research explores designing a hybrid renewable energy system design while taking into account long-range uncertainties of 20 years.

**3 - Modeling the Impact of Natural Hazards on the Serviceability of Infrastructure Systems: A Bayesian Approach**

Jin-Zhu Yu, Vanderbilt University, Nashville, TN, United States, Mackenzie G. Whitman, Hiba Baroud

The ability to make accurate predictions of failure or recovery measures for infrastructure systems is often hindered by the lack of data and uncertainty of hazards. To address this challenge, this study presents a framework that incorporates a Bayesian updating mechanism of network component fragility into the evaluation of the overall serviceability of an infrastructure network under multiple hazard scenarios. This framework allows for better understanding of the subsequent performance of the individual components and the entire network as new data becomes available. A case study of a water distribution network is presented to illustrate the framework.

**4 - Multi-stage Prediction for Zero-inflated Hurricane Induced Power Outages**

Sara Shashaani, University of Michigan, Ann Arbor, MI, 48105, United States, Seth Guikema, Chengwei Zhai, Jordan V. Pino, Steven M. Quiring

Predictive models on hurricane power outages can be built via statistical learning methods that use past hurricanes data to capture the effects of several climatological and environmental variables on the power systems. Classical data minim methods and accuracy metrics are misleading for datasets with the majority of their response variables being zero. To deal with the zero-inflation in the power outage datasets, we develop and validate a 3-stage framework for three historic hurricanes and predict the outages of three recent hurricanes in the central Gulf region. The results show improvement over the traditional approaches.

**5 - Impact of Climate Model Uncertainties in Projecting Long Term Regional Energy Demand**

Sayanti Mukherjee, Purdue University, West Lafayette, IN, United States, Panteha Alipour, Roshanak Nateghi

The uncertainties in projecting long-term energy demands are not only associated with stochasticity in future socio-economic conditions, population changes or technology infusion, but also with climate projections as provided by the General Circulation Models (GCMs). Uncertainties attributed to climate projections mostly arise from the structure and processes within the GCMs, leading to projection divergence across the models. The purpose of this study is to provide an assessment of how the divergence in climate projections influence the long-term regional energy demand projections. The proposed framework will help the stakeholders in risk-informed long-term utility planning.

## ■ SA42

North Bldg 227A

**Joint Session ISim/APS: Rare Events and Stochastic Optimization**

Sponsored: Simulation

Sponsored Session

Chair: Raghu Sasupathy, Purdue University, West Lafayette, IN, 47907, United States

**1 - Simulation of Bipartite or Directed Graphs with Prescribed Degree Sequences Using Maximum Entropy Probabilities**

Enrique Lelo de Larrea, Columbia University, 403 Uris Hall, Columbia Business School, New York, NY, 10027, United States, Paul Glasserman

We propose an algorithm for simulating bipartite or directed graphs with given degree sequences, motivated by the study of financial networks with partial information. Our algorithm sequentially computes certain "maximum entropy matrices, and uses the entries of these matrices to assign probabilities to edges between nodes. We prove the correctness of the algorithm, showing that it always returns a valid graph and that it generates all valid graphs with positive probability. We illustrate the algorithm in an example of an inter-bank network.

**2 - Asymptotically Optimal Chance Constrained Optimization Approximations in Rare Event Regimes**

Fan Zhang, Stanford University, 450 Serra Mall, Stanford, CA, 94305, United States, Jose Blanchet, Bert Zwart

Chance constrained optimizations are known to be NP hard, but it can be approximated by scenario approach when the tolerance-violation is small. The number of sampled constraints in conventional scenario approach is inversely proportional to the tolerance-violation, which is computationally expensive when the chance constraints become increasingly rare. In this talk, we applied importance sampling to construct a rare event simulation estimator, and the number of sampled constraints logarithmically grows with respect to the tolerance-violation

**3 - Feasibility Check with Recycled Observations**

Yuwei Zhou, Georgia Institute of Technology, Atlanta, GA, United States, Sigrun Andradottir, Seong-Hee Kim, Chuljin Park

We consider the problem of repeatedly finding a set of feasible or near-feasible systems among a finite number of simulated systems in the presence of stochastic constraints when the values of thresholds in the constraints change. Instead of restarting feasibility check from scratch for a new set of constraint threshold values, we recycle every observation collected from the previous feasibility check. We show that feasibility check with recycled observations achieves higher statistical guarantee and higher efficiency in terms of the number of observations than feasibility check with restart.

**4 - A Decomposition Approach for Generating Correlated Random Vectors**

Oscar O. Guaje, Universidad de los Andes, Cra. 1 #18a-12, Bogotá, 111021, Colombia, Andres L. Medaglia, Jorge A. Sefair

Current methods for generating correlated random numbers often rely on specific properties of the probability distributions of the input variables. We present a method based on mixed-integer programming that induces correlations to a set of random vectors without making any strong assumptions on the distribution of the random variables nor on the correlation structure. To improve the computational performance of our method we propose a column generation procedure. Our results compare favorably against the state-of-practice in terms of speed and solution quality. Finally, we illustrate its use in simulation where multiple input variables share a correlation structure within a flow process.



## ■ SA43

North Bldg 227B

### The Future of Energy: A Systems Perspective

Emerging Topic: Energy and Climate

Emerging Topic Session

Chair: Benjamin D. Leibowicz, University of Texas-Austin, Austin, TX, 78712-1591, United States

#### 1 - U.S. Energy Infrastructure of the Future: Electricity Capacity Planning through 2050

Gopika G. Jayadev, University of Texas-Austin, Austin, TX, United States, Benjamin D. Leibowicz, Erhan Kutanoglu

We develop an integrated mixed-integer programming framework that optimizes long-term capacity investments and operational schedules for energy supply and end-use technologies. Our methodology extends an existing energy-economic modeling framework. Our framework simultaneously optimizes generation investments, the locations of these investments as well as the transmission network linking the generation facilities to different demand regions. We analyze our model for the US electricity market and present our findings.

#### 2 - A Stochastic Model of Socio-technical Regime Transitions Featuring the Impact of Policy Decisions

Max Brozynski, University of Texas, Austin, 1240 Barton Hills Dr, #107, Austin, TX, 76109, United States

The study of energy transitions has enjoyed much attention recently due to the scientific community's focus on stabilizing greenhouse gas emissions. But, while historical perspectives on how energy systems transition from one regime to another are informative, a formal mathematical theory of energy system transitions is needed to bridge the gap between observing past experiences and predicting future behavior. In this paper, we present a model of socio-technical regime transitions formulated as a Markov decision process. This stochastic model captures key features of such transitions, including economies of scale, path dependence, consumer choice, and the impacts of policy decisions.

#### 3 - Grid-integrated Renewable Energy Resource Assessments: Wind and Solar Supply Curves for China

Michael R. Davidson, Harvard Kennedy School, One Brattle St., 356H, Cambridge, MA, 02138, United States

Renewable energy resource assessments are important for long-term power systems planning but typically ignore or downplay operational details. In this study, building on earlier wind-focused work, we present an efficient algorithm for creating a combined solar and wind "supply curve for China building on fine geographic and hourly resolution data. We compare operational outcomes with traditional economic dispatch optimizations.

#### 4 - Improved Energy Systems Planning and Decision-making using Integrated Assessment Research

Zarrar Khan, Pacific Northwest National Laboratory, 5825 University Research Court, Suite 3500, College Park, MD, 20740, United States, Gokul Iyer

This talk will discuss recent forays in integrated assessment research to improve representations of spatial, temporal, and process detail in representations of the energy sector. The talk will present applications of a U.S. focused version of the Global Change Assessment Model (GCAM-USA) to highlight the value of detailed modeling of the U.S. energy sector within the context of broader interactions of the energy sector with the economy, agriculture, land-use, climate, and water systems.

## ■ SA44

North Bldg 227C

### Joint Session ENRE/Practice Curated: Data Analytics for Power Systems

Sponsored: Energy, Natural Res & the Environment/Electricity

Sponsored Session

Chair: Ming Jin, UC Berkeley, Berkeley, CA, 94720, United States

Co-Chair: Javad Lavaei, University of California, UC, Berkeley, CA, United States

#### 1 - Data Driven Power Flow Analysis in Distribution Grids with Incomplete System Information

Yang Weng, Arizona State University, 551 E. Tyler Mall, ERC 563, Engineering Research Center (ERC), Tempe, AZ, 85281, United States, Jiafan Yu, Ram Rajagopal

The increasing integration of distributed energy resources calls for new monitoring and operational planning tools to ensure stability and sustainability in distribution grids. One idea is to use existing tools in transmission grids and some primary distribution grids. However, they usually depend on the knowledge of

the system model. To solve the modeling problem, we propose a support vector regression (SVR) approach to reveal the mapping rules between different variables and recover useful variables based on physical understanding and data mining. We illustrate the advantages of using the SVR model over traditional regression method which finds line parameters in distribution grids.

#### 2 - Real-time Prediction of the Duration of Distribution System Outages

Baosen Zhang, University of Washington, Seattle, WA, United States, Aaron Jaech, Mari Ostendorf, Daniel Kirschen

This paper addresses the problem of predicting duration of unplanned power outages, using historical outage records to train a series of neural network predictors. The initial duration prediction is made based on environmental factors, and it is updated based on incoming field reports using natural language processing to automatically analyze the text. Experiments using 15 years of outage records show good initial results and improved performance leveraging text. Case studies show that the language processing identifies phrases that point to outage causes and repair steps.

#### 3 - Data-driven Learning Methods for Detecting and Mitigating Load Redistribution Attacks

Lalitha Sankar, Arizona State University, 551 E. Tyler Mall, Tempe, AZ, 85281, United States

The electric power grid is a critical cyber-physical infrastructure that is vulnerable to data injection attacks. We present data-driven detection techniques against a wide class of cyberattacks that maliciously redistribute loads by modifying measurements including nearest neighbor, SVM, and neural networks. The detectors are both trained and tested using publicly available PJM zonal load data. Mapping the dataset to the IEEE 30-bus system, the efficacy of the detectors, designed in a semi-supervised manner with labeled non-anomalous historical data, is tested with both attacked and non-anomalous data. We show that all three detectors designed are very accurate.

## ■ SA45

North Bldg 228A

### Power System Resilient Design and Optimization

Sponsored: Energy, Natural Res & the Environment/Electricity

Sponsored Session

Chair: Seyedamirabbas Mousavian, Clarkson University, Potsdam, NY, 13699-5790, United States

#### 1 - An Accurate Charging Model of Battery Energy Storage

Mrvoje Pandzic, University of Zagreb, Unska 3, Zagreb, 10000, Croatia

Battery storage is becoming an important part of modern power systems and its operation model needs to be integrated in the market clearing and investment models. However, models that commonly represent the operation of large-scale battery energy storage used in scientific literature are inaccurate. In case energy storage is unable to absorb or deliver scheduled quantities, market players might suffer monetary losses and power system operation might be jeopardized. In this work, an accurate battery charging model is formulated, which closely reflects the actual battery charging constraints.

#### 2 - Enhancing Distribution Resilience with Mobile Energy Storage: A Progressive Hedging Approach

Yury Dvorkin, New York University, Metrotech Center, Fay Street, Brooklyn, NY, 11201, United States

We propose a two-stage optimization model that optimizes investments in transportable ES units, i.e. those that can be moved using regular transportation routes, in the first stage and can re-route them in the second stage to form dynamic microgrids and to avoid the expected load shedding caused by natural disasters. We show that this model cannot be solved efficiently with off-the-shelf solvers, even in relatively small instances, and therefore apply a progressive hedging algorithm.

#### 3 - Robust Estimation of Reactive Power for an Active Distribution System

Zhengshuo Li, Southern Methodist University, Dallas, TX, United States, Jianhui Wang, Hongbin Sun, Feng Qiu, Qinglai Guo

Reactive power potential (RPP) of an active power system (DPS) is the range between the maximal inductive and capacitive reactive power the DPS can reliably provide to transmission networks. This paper proposes a robust RPP estimation method based on two-stage robust optimization, where the RPP is pre-estimated in the first stage and its robust feasibility for every instance of the uncertainty in the DPS is checked in the second stage. The column-and-constraint generation algorithm is adopted to solve this model in finite iterations. Case studies confirm that this robust method excels in yielding a completely reliable RPP.

#### 4 - Communication-constrained Expansion Planning for Resilient Distribution Systems

Russell Bent, Los Alamos National Laboratory, Lanl, Mail Stop C933, P.O. Box 1663, Los Alamos, NM, 87545, United States, Geunyeong Byeon, Pascal Van Hentenryck, Harsha Nagarajan

We discuss the Optimal Resilient Design Problem for Distribution and Communication Systems (ORDPDC). The ORDPDC is formulated as a two-stage stochastic mixed-integer program that captures the physical laws of distribution systems, the communication connectivity of smart grid components, and a set of scenarios which specifies which components are affected by potential disasters. We discuss an exact branch-and-price algorithm for the ORDPDC which features a strong lower bound and a variety of acceleration schemes to address degeneracy. The results demonstrate the significant impact of the network topologies on the expansion plans and costs, and the computational benefits of the approach.

## ■ SA46

North Bldg 228B

### Assessing and Managing Interdependencies of Complex Networks

Sponsored: Energy, Natural Res & the Environment/Energy Sponsored Session

Chair: Feng Qiu, Argonne National Laboratory, Lemont, IL, 60439, United States

Co-Chair: Matteo Spada, Paul Scherrer Institut, Villigen PSI, 5232, Switzerland

#### 1 - Coordinated Operations of Power Grid and Water System with Renewable Integration

Daniel Zuniga, Neng Fan, University of Arizona, Tucson, AZ, USA.

In this talk, we propose the multi-level robust optimization model for the coordinated operations of power grid and water system with the integration of renewable energy. To solve this complex and large-scale problem, some decomposition-based algorithms will be designed. Some numerical experiments will be performed to validate model and check the efficiency of proposed algorithms.

#### 2 - Resilient Planning of Power Grid and Water System with Renewable Integration

Daniel A. Zuniga Vazquez, University of Arizona, Tucson, AZ, United States, Neng Fan

In this talk, we propose the multi-level robust optimization model for the coordinated planning of power grid and water system with the integration of renewable energy. To solve this complex and large-scale problem, some decomposition-based algorithms will be designed. Some numerical experiments will be performed to validate model and check the efficiency of proposed algorithms.

#### 3 - Secure Allocation of Power Reserves with Large Renewable Penetration Under Gas Transmission Constraints

Giovanni Sansavini, ETH Zurich, Zurich, Switzerland, Andrea Antenucci

Gas-fired generation provides flexibility to the power system for peak-load shaving and reserve allocation. Large penetration of renewables strengthens the gas-electric coupling. Constraints to the operations of the gas transmission system endanger the security of power supply. We assess the impact of gas constraints on the day-ahead electric power and reserve scheduling. The day-ahead scheduling of generator dispatch and reserves is determined via a stochastic, N-1 secure optimization. Minimum pressure constraints update the scheduling. In scarce-wind conditions, reserve planning including gas constraints prevents pressure violations caused by unexpected wind fluctuations.

#### 4 - Robust Co-optimization Planning of Interdependent Electricity and Natural Gas Systems with a Joint N-1 and Probabilistic Reliability Criterion

Lei Wu, Clarkson University, 8 Clarkson Avenue, P.O. Box 5720, Potsdam, NY, 13676, United States

As the sharp growth of gas-fired power plants and the emergence of Power-to-Gas (PtG) intensify interdependency between electricity and gas systems, it is imperative to co-optimize the two systems for improving overall efficiency. A long-term robust co-optimization planning model is discussed, for minimizing total investment and operation costs. Beside generators, transmission lines, gas suppliers, and pipelines, PtGs and gas compressor stations are also considered as investment candidates to effectively handle wind uncertainty and compensate pressure losses. A joint N-1 and probabilistic reliability criterion to promote economical and reliable planning solutions is also considered.

#### 5 - Estimating the Impact of Natural Gas Transmission Pipeline Network Disruptions on Power Generation

Charles M. Macal, Argonne National Laboratory, Lemont, IL, United States, Eric Tatara, Jordan Jalying, Victor M. Zavala, Stephen Folga, Guenter Conzelmann

Reliable natural gas delivery is critical for operators of gas-fired electric generation plants. Gas pressures and flows at delivery points must be maintained at the required conditions of the plant to ensure continuous operation. We present a method to estimate the impacts of gas pipeline disruptions on power generation using a model of dynamic flow and pressure using the graph-based modeling framework Plasmio.jl. Cases studies are presented to illustrate the model capabilities in an interstate-scale natural gas transmission pipeline that include compressor station power disruptions and pipeline breaks. The model time and space resolution enable us to provide near real-time capabilities.

#### 6 - Risk-based Distributionally Robust Optimal Power Flow with Dynamic Line Rating

Rui Gao, Georgia Institute of Technology, 755 Ferst Drive NW, ISyE Main Building, Atlanta, GA, 30332-0205, United States

We propose a risk-based data-driven distributionally robust approach to investigating the optimal power flow with dynamic line rating. The risk terms, including penalties for load shedding, wind generation curtailment and line overload, are embedded into the objective function. To robustify the solution, we consider a distributional uncertainty set based on the second order moment, that captures the correlation between wind generation outputs and line ratings, and also the Wasserstein distance, that hedges against data perturbations. We show that the proposed model can be reformulated as a convex conic program. Approximations of the proposed model are suggested, which leads to a significant reduction of the number of the constraints. For practical large-scale test systems, a distributionally robust optimal power flow model with Wasserstein-distance-based distributional uncertainty set and its convex reformulation are also provided. Simulation results on the 5-bus, the IEEE 118-bus and the Polish 2736-bus test systems validate the effectiveness of the proposed models.

## ■ SA47

North Bldg 229A

### Change Detection and Prognostics for Transient Real-World Processes Using Streaming Data

Emerging Topic Session

Chair: Lewis Ntamo, Texas A&M University, 3131 TAMU, College Station, TX, 77843, United States

#### 1 - Change Detection and Prognostics for Transient Real-World Processes Using Streaming Data

Satish Bukkapatnam, Texas A&M University, 3131 TAMU, 4020 Emerging Technologies Building, College Station, TX, 77843, United States, Ashif Sikandar Iquebal

Recent advances in sensor arrays and imaging systems have spurred interest in analyzing high-dimensional, streaming time series data from real-world complex systems. These time series data capture the dynamic behaviors and causalities of the underlying processes and provide a computationally efficient means to predict and monitor system state evolution. More pertinently, they can provide the ability to detect incipient and critical changes in a process, which is essential for real-time system integrity assurance. However, effective harnessing of information from these data sources is currently impeded by the mismatch between the key assumption of stationarity underlying most change detection methods and by the nonlinear and nonstationary (transient) dynamics of most real-world processes. The current approaches are slow or simply unable to detect qualitative changes in the behaviors that lead to anomalies. For most real-world systems, the vector field of state dynamics is a nonlinear function of the state variables, i.e., the relationship connecting intrinsic state variables with their autoregressive terms and exogenous variables is nonlinear. Time series emerging from such complex systems exhibit aperiodic (chaotic) patterns even under steady state. Also, since real-world systems often evolve under transient conditions, the signals so obtained tend to exhibit myriad forms of nonstationarity. This tutorial presents a delineation of these diverse transient behaviors, and a review of advancements in change detection and prognostication methods for nonlinear and nonstationary time series. We also provide a comparison of their performances in certain real-world manufacturing and health informatics applications.

## ■ SA48

North Bldg 229B

**Integrated Multi-scale Multi-sector Modeling of Energy Systems**Sponsored: Energy, Natural Res & the Environment/Energy  
Sponsored Session

Chair: Gokul C. Iyer, Pacific Northwest National Laboratory, 5825 University Research Court, College Park, MD, 20740, United States

**1 - Introduction to Integrated Multi-model Frameworks to Improve Decision-making Capabilities Across Spatial and Temporal Scales in the Energy Systems**

Gokul Iyer, Pacific Northwest National Laboratory, 5825 University Research Court, Suite 3500, College Park, MD, 20740, United States

This talk will give an overview of modeling efforts to integrate models with different degrees of temporal, spatial, and sectoral detail to provide improved decision-making capabilities about energy systems and infrastructure planning within the context of the broader energy-water-land-climate nexus.

**2 - Structural Uncertainty Across Disparate Energy-economy Modeling Frameworks: Reeds and GCAM-USA Consistency Under Alternative Earth Futures**

Stuart Cohen, National Renewable Energy Laboratory, 15013 Denver West Parkway, RSF 300, Golden, CO, 80401, United States, Gokul Iyer, Maxwell Brown

Robust decision support assimilates information from multiple tools across the relevant scale and scope. However, these tools often differ in structure and function, yielding inconsistent results that confound the decision process. Previous work sought a robust electric sector expansion model framework by harmonizing GCAM-USA, a multi-sector human-Earth system model, with the ReEDS electricity sector model. I'll describe progress achieving consistent electricity and energy-economy solutions under many socioeconomic, technology, and market futures. I'll examine structural uncertainties affecting solution consistency and consider the broader implications for decision support.

**3 - The Future of Natural Gas Infrastructure Development in the United States**

Felipe A. Feijoo, Pontificia Universidad Católica de Valparaíso, Av. Brasil 2241, Office 6-8, Valparaíso, Chile, Gokul Iyer, Charalampos Avraam, Sauleh Ahmad Siddiqui, Leon Clarke, Matthew T. Binsted, Sriram Sankaranarayanan, Sriram Sankaranarayanan, Pralit Patel, Marshall Wise, Nathalia Prates, Evelyn Torres-Alfaro

This study couple a global human-Earth system model with state-level detail in the U.S. (GCAM-USA) with a natural gas infrastructure investment model (NANGAM) to examine inter-state natural gas pipeline infrastructure development in the U.S. We show that existing pipeline infrastructure is insufficient to satisfy the increasing demand. The geographic distribution of investments within the U.S. is heterogeneous and depends on the capacity of existing infrastructure as well as the magnitude of increase in demand. Our results also illustrate the risks of under-utilization of pipeline capacity

**4 - Interconnection Cost Implications of Future Power Generation Capacity Expansion in the United States**

Chris Vernon, Pacific Northwest National Laboratory, WA, United States, Gokul Iyer, Ian P. Kraucunas, Nathalie Voisin, Mohamad Hejazi, Matthew T. Binsted, Matthew O'Connell, Pratik L. Patel

Long-term electric power sector planning is a complex process that is rooted in system dynamics to assess the timing and magnitude of investments in infrastructure within the context of potential vulnerabilities. Assessing these dynamics requires a multi-sector, multi-scale modeling approach that captures socioeconomics, electricity supply and demand, and the impediments and distribution of the power generation sources. This research evaluates the impact of achieving future capacity expansion plans to the resulting technology-specific interconnection costs by pairing an integrated human-Earth system model (GCAM-USA) with the Capacity Expansion Regional Feasibility model (CERF).

## ■ SA49

North Bldg 230

**Joint Session ENRE/Practice Curated: Advanced Analytics in Oil & Gas Production and Exploration**Sponsored: Energy, Natural Res & the Environment/Natural Resources Petrochemicals  
Sponsored Session

Chair: Damian Burch, ExxonMobil Upstream Research Company, Houston, TX, United States

**1 - Bayesian Modeling and Decision Making for a Well System**  
Rujian Chen, Massachusetts Institute of Technology

We are interested in modeling a large off-shore oil well system with complex multi-phase fluid flows. Previous optimization-based learning methods failed to capture the high uncertainty in the system arising from noisy and missing measurements. In this work, we adopt a Bayesian framework to infer system parameters as well as characterize their uncertainty. We use a Gaussian process to model the flow simulation and develop an approximate model with a tractable inference method. We use synthetic to data show the fidelity of the approximate model and use Bayesian model validation techniques to show the predictive accuracy of the model. Finally, we develop new experiment design approach which brings time and cost savings compared to previously used empirical methods.

**2 - The Effect of Technology on Importance of Geologic Parameters for Shale Well Productivity: Cross-Play Analysis**

Svetlana Ikonnikova, University of Texas at Austin, Austin, TX, United States, Katie Smye, Scott Hamlin, Robin Dommissie, Frank Male

This study of Haynesville, Fayetteville, and Marcellus shale plays explores the role of geologic parameters versus completion technology? Applied machine learning methods (random forest and model-based recursive partitioning) reveal the set of variables, which explain individual well productivity. The analysis focuses on exceptionally good wells in geologically mediocre, e.g. ductile, areas to understand whether "poor rock quality can be compensated by completions and be economical. We find that good "outliers exist, with productivity being statistically explained by technology-related changes, such as optimized completions (and field experience) making "poor zones economic.

**3 - Transdimensional Full Waveform Inversion Using a Hamiltonian Formulation**

Mrinal K. Sen, University of Texas at Austin

Abstract not available.

**4 - Data-driven Methods for Well Connectivity**

Damian Burch, PhD, ExxonMobil Upstream Research Company, 22 S. Peaceful Canyon Circle, The Woodlands, TX, 77381, United States, Akash Mittal, Tripti Kumari

Making the best development and production decisions in the oil & gas industry requires a detailed understanding of subsurface flow paths. Most critically, we need to understand if and how pressure from injection wells might affect nearby producer wells. Unfortunately, this information usually cannot be directly imaged, so indirect methods are required to infer subsurface flow paths from sparse surface measurements. In this talk, we will discuss methods that combine simple physical models with data-analytic algorithms for detecting and quantifying well connectivity.

**5 - Real-time Solution of a Pursuit-Evasion Game for Ice Management**

Matthew W. Harris, ExxonMobil Upstream Research, Magnolia, TX, United States

Ice management systems provide a rational basis for risk-based decisions, and they involve estimating the probability of an ice impact and associated time. A differential pursuit-evasion game perspective provides conservative estimates for miss distance and time. Such problems are generally difficult to solve since the direct methods of optimal control do not apply. However, the state space can be partitioned to identify closed-form solutions or a reduced set of algebraic equations. It so happens that the degenerate solution types admit closed-form solutions while regular solution types do not. Examples of each are shown.



## ■ SA50

North Bldg 231A

### Joint Session Practice/Practice Curated:Editor's Cut #1: Cybersecurity, Elections, Transportation, Agribusiness

Sponsored: INFORMS Section on Practice (formerly CPMS)

Sponsored Session

Chair: Carrie Beam, University of Arkansas, Walnut Creek, CA, 94596, United States

#### 1 - Moderator - Editor's Cut #1 (Cybersecurity, Elections, Transportation, Agribusiness)

Robin Lougee, IBM Research, IBM TJ Watson Research Center, 1101 Kitchawan Road, Yorktown Heights, NY, 10598, United States

This panel will cover the Cybersecurity, Elections, Transportation, and Agribusiness issues of Editor's Cut. Come learn more about the case studies, videos, and other journal articles available free, online

#### Panelists

Scott Nestler, University of Notre Dame, 51344 Pebble Beach Court, Granger, IN, 46530, United States  
 Alan Erera, Georgia Institute of Technology, School of Industrial & Systems Eng, Atlanta, GA, 30332-0205, United States  
 Saurabh Bansal, Penn State University, 405 Business Building, State College, PA, 16801, United States  
 Sam Ransbotham, Boston College, Fulton Hall 460A, 140 Commonwealth Avenue, Chestnut Hill, MA, 02467, United States

## ■ SA51

North Bldg 231B

### Advances in Project Management

Emerging Topic: Project Management and Scheduling, in Memory of Joe Leung,

Emerging Topic Session

Chair: Janne Kettunen, The George Washington University, Washington, DC, 20052, United States

#### 1 - Using Reminders to Focus Attention

Suvrat Dhanorkar, Pennsylvania State University, 466 Business Building, University Park, PA, 16802, United States, Enno Siemsen

How does one ensure that tasks get done, even if one has only limited authority and control over them? This is a fundamental problem of project management. Additionally, since tasks do not exist in a vacuum, organizations constantly require their employees to multi-task and switch attention from one task to another. We use energy efficiency projects as the research context and use a combination of archival and experimental data to show that reminders serve as a key managerial lever to focus the employee attention to specific tasks.

#### 2 - Project Portfolio Selection: Disjunctive Stochastic Programming Formulations with Joint Chance Constraint

Janne Kettunen, The George Washington University, Department of Decision Sciences, 2201 G. Street NW, Washington, DC, 20052, United States, Miguel Lejeune

The main goals of start-up companies in new product development (NPD) are to attain a reliable return level and deliver this return level fast. Achieving these goals is complicated due to uncertainties in projects' returns and durations. We develop new models for the NPD capturing the above goals. The first model is static representing the waterfall product development process whereas the second model is dynamic representing the agile product development process. We design a reformulation method and a new decomposition algorithm to solve these problems. We apply our models to an US-based software start-up company and derive managerial insights.

#### 3 - Information Exchange in Parallel Search

Fang Ni, University of Cologne, Cologne, Germany, Fabian J. Sting

This paper studies parallel search for technological innovation by multiple teams, which is a relevant context for organizational innovation. Within such a setting, a critical issue is how to organize information exchange among the searching teams. The study employs an agent-based simulation approach to identify optimal communication strategies for the firm.

#### 4 - Planning, Tracking, and Reducing Project Value at Risk

Tyson R. Browning, Texas Christian University, Neeley School of Business, TCU Box 298530, Fort Worth, TX, 76129, United States

Uncertainty, risk, and rework challenge projects to meet goals and deliver anticipated value. Conventional techniques for planning and tracking earned value do not account for these. I present a methodology for planning and tracking

cost, schedule, and performance in terms of a project's key value attributes and threats to them. It considers how high the "bar is set for a project (its set goals) and therefore how challenging and risky it will be. A project's capabilities as a "jumper (to clear the bar and meet its goals) determine the portion of its value at risk (VaR). Progress occurs as VaR is reduced: activities "add value by chipping away at the project's "anti-value, the risks that threaten value.

#### 5 - Capacity Planning for Project Management by Adjustable Distributionally Robust Optimization

Daniel Zhuoyu Long, Chinese University of Hong Kong, Room 605, William M. W. Mong Engineering Building, Hong Kong, Antonio J. Conejo, Nicholas G. Hall, Runhao Zhang

Many project companies use outsourced providers which require capacity reservation. Capacity reservation decisions provide access to outsourced services that enable project crashing, but must be made before task durations are realized. We model these decisions with the consideration of worst case distribution. Once task durations are realized, the project company makes decisions about fast tracking and outsourced crashing. We model the company's objective using the target-based measure. We compare the performance of the model against benchmarks from the literature, and show that it provides lower risk and greater robustness to distributional information.

## ■ SA52

North Bldg 231C

### Social Media and Financial Information

Emerging Topic: Social Media Analytics

Emerging Topic Session

Chair: Soo Jeong Hong, PhD, Michigan State University, East Lansing, MI, United States

#### 1 - Social Media Disclosure and Analysts as Information Intermediaries

Kwangjin Lee, Michigan State University, 31 Middlevale Road, 1645 f, East Lansing, MI, 48823, United States

Social media provide chances of direct communication between firms and investors. On one hand, it may reduce the information intermediary role of financial analysts. On the other hand, information overload increases the demand for financial analysts' role as information intermediaries. Therefore, it is an empirical question whether prevalence of social media disclosure substitute or complement the traditional intermediaries, financial analysts. I investigate the effect of social media disclosure on the market reaction to forecast revisions and find social media disclosures complement rather than substitute for the intermediary role of financial analysts, consistent with mosaic theory.

#### 2 - Variational Autoencoders and Infinite Edge Partition Models for Text Modeling and Community Detection: Evidence from Yelp.com Review

Hyunsang Son, The University of Texas at Austin, Austin, TX, United States

Recent works from Natural Language Process (NNP) found that variational autoencoders (VAE) with appropriate decoders such as Long short-term memory (LSTM) better on generative text modeling. By adopting another newly emerged research trends in social network analysis called community detection, this paper will investigate how user networks differ in yelp.com review conditioning on sentiment label.

#### 3 - The Role of Public Sentiment and Firm Crisis Response Strategy on Twitter in Stock Markets During Firm Crisis Situations

Soo Jeong Hong, Michigan State University, 404 Wilson Rd, Room 309, East Lansing, MI, 48824, United States, Kwangjin Lee, Jinse You

The importance of social media in prediction of stock prices is increasing as the individual investors' and firm's social media usage has become prevalent. We seek the associations between sentiment of Twitter messages and stock price behavior during firm crisis situations. This paper is focused on gaining deeper insights into investors' behavior in order to minimize financial and reputational damages on the firms.

## ■ SA53

North Bldg 232A

### Auction Markets with Non-convexities

Sponsored: Auction and Marketing Design

Sponsored Session

Chair: Robert Day, University of Connecticut, Storrs, CT, 06269-1041, United States

#### 1 - Investment Effects of Pricing Schemes for Non-convex Markets

Jacob Mays, Northwestern University, 2145 Sheridan Road, Room C230, Evanston, IL, 60208, United States

Jacob Mays, Federal Energy Regulatory Commission, Washington, DC, United States, David Morton, Richard O'Neill

Non-convex markets, such as those organized by electricity system operators, lack uniform clearing prices. To help resolve the incentive compatibility issues that arise when clearing these markets, operators have introduced a variety of price formation and uplift payment schemes. We investigate the impact that the choice of pricing scheme can have on generator entry and exit decisions. Our results suggest that despite the presence of fixed production cost elements, prices derived from marginal costs support the optimal capacity mix.

#### 2 - Economizing the Uneconomic: Markets for Sustainable, Reliable, and Price Efficient Electricity

Mohammad Rasouli, Stanford University, 473 Via Ortega, Room 268, MS 4020, Stanford, CA, 94305, United States, Demosthenis Teneketzis

The electricity policy targets aim to provide sustainable and reliable electricity with efficient prices under uncertain demand. Any solution addressing a subset of the policy targets can affect the others. Whereas most of the existing studies focus on one of the targets and analyze existing solutions, we focus on implementing all of the above policy targets by adopting a design approach. We develop a framework for designing efficient auctions with constraints that results in market implementations of the above electricity policy targets. Our results highlight that all policy targets can be achieved without any price-cap or market monitoring, and provide clear answers to major policy debates.

#### 3 - Fast Core Pricing for Rich Advertising Auctions

Rad Niazadeh, Stanford University, 353 Serra Mall, Gate BLDG, Office 484, Stanford, CA, 94305, United States, Jason Hartline, Nicole Immorlica, Mohammad Reza Khani, Brendan Lucier

As online ad offerings become increasingly complex, the sale of web advertising space increasingly resembles a combinatorial auction with complementarities. In this setting, GSP is not well-defined and truthful combinatorial auctions, e.g. VCG, can yield unacceptably low revenue. Core selecting auctions (Day and Milgrom [2007]) boost revenue. Motivated by this, we give a combinatorial algorithm to find a bidder-optimal core point with almost linear calls to welfare-maximization oracle. We also run experiments on the Microsoft Bing Ad Auction platform with decorations: core pricing generates almost 100% more revenue than VCG, and 20% more revenue than the standard GSP auction on average.

#### 4 - Simple and Approximately Optimal Pricing for Proportional Complementarities

Kira Goldner, University of Washington, Seattle, WA, United States

Most work in optimizing revenue with complementary valuations models the buyer's value for a bundle as additive over independent values for each subset. Instead, we model the complementarities as proportional to the buyer's base valuations for each item, and these proportionalities are known market parameters. We give a simple pricing scheme that achieves approximately-optimal revenue and affirms the intuition that selling separately is not a good mechanism to use in the case of complementarities. Our scheme achieves an approximation factor of a constant for pairwise item boosts, and when the boosts are for larger subsets given by a hypergraph, of the minimum of two parameters of the hypergraph.

## ■ SA54

North Bldg 232B

### BOM Session (TONG)

Sponsored: Behavioral Operations Management

Sponsored Session

Chair: Jordan Tong, PhD, University of Wisconsin, Madison, WI, United States

#### 1 - Increased Transparency in Procurement: The Role of Peer-Effects

Ignacio Rios, Stanford, Ruth Beer, Daniela Saban

We study the effects of increased transparency in settings where purchasing decisions are delegated to individual employees as opposed to being centrally managed by the organization. We show that there exists a spillover region where an employee is more likely to choose the expensive supplier when he observes that his peer did so, and we confirm this finding experimentally. We also find that

employees whose decisions are observed are less likely to choose the expensive supplier, and this behavior is aligned with what is considered more socially appropriate. Thus, we argue that these peer-pressure effects are better explained by a model of social norms rather than a model of reciprocity.

#### 2 - On the Non-equivalence of Trade-ins and Upgrades in the Presence of Framing Effect: Experimental Evidence and Implications for Theory

Mahdi Mahmoudzadeh, Georgia Institute of Technology, Scheller College of Business, 800 West Peachtree Street NW, Atlanta, 30308, Georgia

Manufacturers of durable goods often buy back older versions of their products from customers to induce them to switch to improved versions. Classical model has long ignored the framing of these buyback schemes, i.e., trade-ins or upgrades, and its relevance for consumer behavior and theory. Using reference-point shift mechanism, through controlled experiments we find that the alternative frames are not isomorphic and that they shift customers' reference points. We then use the experimental findings to extend a reference-dependence version of the classical model of trade-ins and upgrades and show that the behavioral extension modifies predictions of the classical model in line with reality.

#### 3 - Sustainable Operations Versus Corporate Social Responsibility: How Value Chain Transparency Influences Choice

Ryan Buell, Harvard Business School, Morgan Hall 429, Boston, MA, 02163, United States, Basak Kalkanci

Amid calls for value chain transparency and greater social and environmental stewardship, companies employ a variety of strategies to mitigate the adverse effects of their operations on people and the environment. Some engage in internal sustainability initiatives, such as paying living wages to workers or investing in innovations that reduce the environmental impact of their processes. Others engage in external initiatives, such as contributing to social causes, or offsetting their emissions to compensate for the impact of their processes. Through a series of field and lab experiments, we investigate how and when transparency into these internal and external efforts affect consumer choice.

#### 4 - Mean Service Metrics: Biased Quality Judgement and the Customer-server Quality Gap

Robert Batt, Wisconsin School of Business, UW-Madison, 5279 Grainger Hall, 975 University Ave., Madison, WI, 53706, United States, Jordan D. Tong

We show that a commonly-observed data aggregation technique can lead to systematic biases in how people infer service quality due to a mathematical gap between the quality that servers deliver and that which customers experience. We use a stylized model to characterize how the gap depends on the structure of the service environment, and we use lab experiments to show that people generally fail to fully correct for differences between server-level and customer-experienced metrics. Finally, we use secondary data in the contexts of education and the air travel industry to get a sense of the potential magnitude of judgment biases in real-world settings.

## ■ SA55

North Bldg 232C

### Topics in New Product Development

General Session

Chair: Evgeny Kagan, Ann Arbor, MI, 48103, United States

#### 1 - Smart Manufacturing via Crowd Sourcing

Onesun Steve Yoo, University College London, London, United Kingdom, Kevin F. McCardle, Christopher S. Tang

We examine a smart crowd-sourcing model of manufacturing practiced widely by leading manufacturers in China. A key feature is the use of virtual images of their products to learn whether there is sufficient demand for them before engaging in costly physical production. Using virtual images are less attractive for consumers (uncertainty of getting the item, delays), so the firms must charge a lower price. We analyze the optimal hybrid approach that combines both use of virtual images (made-to-order) and more traditional production (made-to-stock). We compare it with the current practice of some of the leading Chinese manufacturing firms (e.g., Alibaba, Gaofan), and discuss its efficacy.

#### 2 - Truth or Funds for Your Project

Jochen Schlapp, University of Mannheim, Wilhelm-Leuschner-Str. 241, Griesheim, 64347, Germany, Nektarios Oraopoulos, Niyazi Taneri, Ozge Tuncel

We examine the effectiveness of monetary incentives in eliminating managerial misconduct in competitive resource allocation processes. Whereas economic theory predicts that formal incentives should be sufficient to align managers with the organization's best interests, our laboratory experiments reveal that current theory falls short of acknowledging the importance of the level of trust and trustworthiness between managers competing for resources. We show how an organization can induce higher levels of mutual trust, thus improving the overall effectiveness of the resource allocation process.

### 3 - Revisiting the Role of Collaboration in Creating Breakthrough Inventions

Manuel Emilio Sosa, INSEAD, 1 Ayer Rajah Avenue, Singapore, 138676, Singapore, Tian Chan, Jurgen Mihm

We use utility and design patent data for 1985-2009 to compare the probability of creating a breakthrough of working alone versus working in a team. Consistent with literature, for utility patents we find that working alone reduces the probability of achieving a breakthrough. Yet this disadvantage of lone inventors disappears for design patents. We theorize and show empirically that the holistic (i.e., nearly non-decomposable) nature of design is a major factor contributing to the relative efficacy of lone designers at achieving breakthroughs. Finally, we show that lone inventors with a large number of past collaborators has improved likelihood of creating breakthroughs and can outperform teams.

### 4 - Gender Preference for Tech & Competition: Very-Large-Scale Field Experimental Evidence from an Internet-of-Things Platform

Nilam Kaushik, University College London, Boston, MA, 02115, United States, Kevin Boudreau

This paper presents results from a field experiment on 112,000 students and alumni of an American university to understand willingness to participate in working on innovation problems related to a new area of technological innovation and commercialization, the Internet-of-Things.

## ■ SA56

West Bldg 101A

### Operations Analytics in Healthcare

Sponsored: Health Applications

Sponsored Session

Chair: Tolga Tezcan, London Business School, London, NW14SA, United Kingdom

#### 1 - Integrating Prediction Algorithms with Physician Decisions

Junchao Ma, Yale School of Management, Yale School of Management, New Haven, CT, 06520, United States, Edieal J. Pinker

Attempts to use machine learning techniques to create personalized predictions in healthcare are becoming common. Adoption of such methods in practice will require integrating them into the decisionmaking processes of physicians. In this talk we will discuss our attempt to better understand how a mortality prediction algorithm for advanced cancer patients can augment physician predictions and decision making regarding end-of-life care.

#### 2 - Dynamic Server Assignment in Multiclass Queues with Shifts

Carri Chan, Columbia Business School, 3022 Broadway, Uris Hall, New York, NY, 10027, United States, Vahid Sarhangian

Nurse staffing decisions in emergency departments (EDs) are typically assigned weeks in advance, which can create staffing imbalances as patient demand fluctuates. In this work, we consider the potential benefits of assigning nurses to different areas within an ED at the beginning of each shift. We study the problem of optimal reassignment of nurses to areas by considering a multiclass queueing model of the system. We analyze an associated fluid control problem and use the solution to develop policies that achieve asymptotically optimal performance under fluid-scaling for the original stochastic system. We find this additional flexibility can substantially reduce waiting times for patients.

#### 3 - Joint Patient Selection and Scheduling: Theory and Application in Proton Therapy

Ruihao Zhu, MIT, Cambridge, MA, United States, Soroush Saghaian, Nikolaos Trichakis

Motivated by the practice of our partner proton therapy center, we develop joint patient selection and scheduling mechanisms. The center has a tight capacity to serve patients, and any patient scheduled beyond the regular capacity incurs an overtime cost. Developing simulations calibrated with data as well as a variety of analytical bounds, we show that an intuitive index policy that takes into account estimations of both class-dependent and time-dependent (a) no-show probabilities, and (b) service durations achieves a good performance. We also shed light on ways to identify the number of patient classes, estimate time-dependent no-show probabilities, and determine patient service durations.

#### 4 - Transfer Rates and Routing of Patients from ICUs to Downstream Units

Andrew Schaefer, Rice University, Department of Computational and Applied Mathematics, United States

We present a model for determining the transfer rates and routing of patients from intensive care units (ICUs) to downstream units within a hospital. Using a utility maximizing objective, we offer a decomposition approach that allows for an efficient solution algorithm in which each ICU determines its individual transfer rate while a network model determines the specific patient routing. We illustrate the model and solution approach with numerical examples and explore how flexible capacity, unit occupancy, fairness constraints, and network topology play a role in the optimal solution.

### 5- A Holistic Data Analytic Approach to Determine Impacts of the Caregiver Advise, Record, Enable (CARE) Act on Reducing Readmission and Mortality Rates among Older Adults

Nichalin S. Summerfield, University of Massachusetts Lowell, OIS Department, One University Avenue, Lowell, MA, 01854, United States, Asil Oztekin

Family caregivers are the front line of providing post-discharge care to patients and preventing hospital readmissions. CARE Act, enacted in 36 states, allows a patient to designate a caregiver and requires hospitals to provide post-discharge training to the caregivers. In this research, we evaluate the impact of the act by examining hospital 30-day readmission and mortality rates before and after the act implementation in New Jersey. We deploy a data analytic approach on 2013 and 2016 Medicare inpatient claims data of patients 65 years and older.

## ■ SA57

West Bldg 101B

### Innovation in Healthcare Delivery

Sponsored: Health Applications

Sponsored Session

Chair: Kamalini Ramdas, London Business School, London, NW1 4SA, United Kingdom

#### 1 - The Effects of Home Health Visit Length on Hospital Readmission

Hummy Song, The Wharton School, University of Pennsylvania, Philadelphia, PA, United States, Elena Andreyeva, Guy David

This study uses a novel dataset on home health care visits to quantify the effects of the length of a post-acute home health visit on hospital readmissions for patients with conditions that are subject to readmission penalties under the Hospital Readmission Reduction Program. Using an instrumental variable approach, we find that an extra minute relative to the average length of a patient's home health visits reduces their readmission likelihood by about 8 percent.

#### 2 - Increasing Patient Engagement Through Shared Medical Appointments

Ryan Buell, Harvard Business School, Morgan Hall 429, Boston, MA, 02163, United States, Kamalini Ramdas, Nazli Sonmez

Through a randomized control trial, we examine the impact of shared medical appointments (SMAs), in which a group of patients with similar chronic conditions meet with a doctor simultaneously, on levels of patient engagement. Relative to traditional one-on-one care models, we study how SMAs affect engagement levels, both during the appointment (such as making eye contact with the physician, engaging in the proceedings, and asking questions) and after (such as complying with prescribed medications in the home). Although SMAs hold obvious promise for improving the efficiency of healthcare, to the extent that they may lead to increased patient engagement, they may result in improved outcomes as well.

#### 3 - Structural Estimation of Kidney Transplant Candidates' Quality of Life Scores

A. Cem Randa, University of Chicago, Booth School of Business, 5807 S. Woodlawn Avenue, Chicago, IL, 60637, United States, Baris Ata, John J. Friedewald

This paper develops a framework for assessing the impact of changes to the deceased-donor kidney allocation policy on the transplant candidates' organ acceptance behavior, the transplant waitlist, organ availability for different patient groups and organ wastage. It advances a fluid model of the transplant waitlist and a dynamic structural model of the transplant candidates' accept/reject decisions for organ offers. Building on these two models, we also provide an equilibrium framework, enabling counterfactual studies for assessing the (unintended) consequences of policy changes.

#### 4 - Deployment Guidelines for Community Health Workers in Sub-Saharan Africa

Jonas Oddur Jonasson, MIT Sloan School of Management, 30 Memorial Drive, E62-588, Cambridge, MA, 02142, United States, Carri Chan, Sarang Deo, Jeremie Gallien

Community health workers (CHWs) are increasingly important to healthcare delivery in many African countries. Leveraging an extensive dataset featuring time, clinical findings, and GPS information for CHW visits in sub-Saharan Africa, we develop a stochastic model describing the health dynamics of a population served by a time-constrained CHW. We report closed-form solutions quantifying the impact of CHW deployment on public health for a special case and build a heuristic to solve a policy maker's CHW deployment problem.



## ■ SA58

West Bldg 101C

### Joint Session HAS/Practice Curated: Healthcare Analytics I

Sponsored: Health Applications

Sponsored Session

Chair: Ozden Onur Dalgic, Massachusetts General Hospital/ Harvard Medical School, Boston, MA, 02114, United States

#### 1 - Predicting the Risk of Critical Events in ALS Disease Using Data Analytics

Ozden Onur Dalgic, Harvard Medical School, Boston, MA, United States, Osman Ozaltin, F. Safa Erenay, Kalyan Pasupathy, Mustafa Y. Sir, Brian Crum

ALS is a neuro-degenerative disease causing continuous decay of motor neurons and muscle atrophy. Patients suffer from losing their abilities to speak, eat, move and. Due to having no permanent treatment, ALS eventually affects all abilities but disease progression shows a great variability. Using medical records of over 500 patients from Mayo Clinic, we analyse the ALS progression pathways, and estimate risks of losing abilities and needing medical interventions (e.g., feeding/breathing tube). We then develop a natural history model to predict the risk of critical events (e.g., using wheelchair) over the course of the disease.

#### 2 - Using Partially Observable Markov Decision Processes to Improve Alzheimers Disease Screening

Saeideh Mirghorbani, University of Alabama, Tuscaloosa, AL, 35401, United States, Sharif Melouk, John Mittenhalt

Family history, genetics, Down syndrome, head injury, high cholesterol levels, high blood pressure, and diabetes are some of the factors that place individuals at a higher risk of developing Alzheimer's disease (AD). To manage this risk and its complications, persons more susceptible to AD should be regularly screened. To determine an optimal screening plan, we develop a finite horizon, partially observable Markov decision process model for individuals transitioning through different stages of AD. The model aims to maximize the Quality Adjusted Life Years (QALY) for an individual.

#### 3 - The Role of Big Data in System Dynamics Modeling

Hamed Kianmehr, Binghamton University, Binghamton, NY, 13905, United States, Nasim S. Sabounchi, Lina Begdache

Our objective in this research is to use big data techniques to enhance system dynamics (SD) modeling regarding the relationship between diet and mental health. We apply our approach to study the relationship between diet and mental health. We estimate the parameters of the system dynamics model by applying some novel big data techniques on a large data set. Then, we feed the calibration parameters in SD models with the new estimations using big data analytics. Big data techniques and SD models can contribute to investigating the causal relationships between nutrition and mental health. The future achievement will enable big data analytics to assist other modeling techniques in the healthcare domain.

#### 4 - Developing Predictive Models for Parkinson's Disease by Analyzing an Imbalanced Dataset

Saeed Piri, University of Oregon, 434 Lillis Business Complex, Eugene, OR, 97403, United States

Parkinson's disease (PD) is a neurodegenerative disorder that affects about one million Americans. In this study, we develop diagnostic models, which use only demographic, lab, and clinical events data. To develop these models, we analyzed a large size imbalanced data. To enhance our models' accuracy, we applied synthetic informative minority oversampling (SIMO) algorithm and extended it to machine learning techniques such as decision tree, logistic regression, and neural network. Finally, we developed an ensemble model by applying confidence margin ensemble approach.

## ■ SA59

West Bldg 102A

### Joint Session HAS/Practice Curated: Empirical Research in Health Care

Sponsored: Health Applications

Sponsored Session

Chair: Daniel Ding, BC, Canada

#### 1 - Workload, Predictive Accuracy, and the Value of Algorithm-enabled Process Innovation: The Case of Sepsis Alerts

Mehmet U. Ayvaci, University of Texas at Dallas, Richardson, TX, United States, Idris Adjerid, Ozalp Ozer

Predictive algorithms have an increasingly important role in supporting the day-to-day operations of businesses. This paper studies how and when algorithm-enabled process innovation (AEPI) creates value, particularly in the

context of changing operational environments and the behavioral responses to algorithmic predictions. We contextualize the broad research problem into the implementation of an alert system in a hospital for early identification and treatment of sepsis. We leverage a rich set of clinical and nonclinical data and econometric approaches to examine the relationship between sepsis AEPI and patient mortality.

#### 2 - Impact of Discharge Policies on Emergency Department Overcrowding

Arshya Feizi, Boston University, 595 Commonwealth Avenue, Boston, MA, 02215, United States, Jillian Berry Jaeker

In a hospital "boarding" occurs when emergency department (ED) patients are stabilized but cannot be admitted to their appropriate wards for further treatment, if required, due to issues such as insufficient capacity in the receiving unit. We investigate how discharge policies may impact ED overcrowding and patient boarding.

#### 3 - How to Improve MRI Hospital Waiting Time – An Empirical Analysis of Geographical Resource Pooling

Yangzi Jiang, Northwestern University, 4174 Kellogg Global Hub, 2211 Campus Drive., Evanston, IL, 60208, United States, Jan A. Van Mieghem, Hossein Abouee Mehrizi

Significant mismatches between demand and capacity in MRI hospitals in Ontario Canada leads to prolonged waiting time which inspired our research of when and to what extent to implement pooling. Using patient-level data gathered from 72 MRI hospitals over 5 years, we conducted an empirical analysis using regional pooling to achieve over 20% wait-time reduction. This research provided the basis for strategic hospital decisions. ?

#### 4 - Do Financial Incentives Change Length-of-stay Performance in Emergency Departments? A Retrospective Study of the Pay-for-performance Program in Metro Vancouver

Yichuan Ding, University of British Columbia, University of British Columbia, 6333 Larkin Drive, Vancouver, BC, V6T 1C3, Canada, Yuren Wang, Eric Park, Garth Hunte

We study whether and how a province-wide P4P program affected ED patient disposition timing. The P4P program provided financial compensation to enrolled hospitals for each ED patient visit that met a certain LOS target. We examined, in 4 EDs, whether the LOS distribution had a discontinuous density near the LOS targets specified by the program, which suggests that patient dispositions may have been completed in order to meet the LOS targets. Our findings provide evidence of organizational responses to P4P incentives and suggest that the P4P program can benefit patients by reducing access blocks, but may also lead to unintended outcomes, such as higher return and admission rates.

## ■ SA60

West Bldg 102B

### Joint Session HAS/Practice Curated: Data and Models in Healthcare Analytics

Sponsored: Health Applications

Sponsored Session

Chair: Joel Goh, NUS Business School, 119245, Singapore

Co-Chair: Shasha Han, National University of Singapore, National University of Singapore, Singapore, Singapore

#### 1 - The Analytics of Bed Shortages: Coherent Metric, Prediction and Optimization

Jingui Xie, University of Science and Technology of China, School of Management, 96 Jinzhai Road, Hefei, 230026, China, Gar Goei Loke, Melvyn Sim, Shao Wei Lam

In practice, healthcare managers often use bed occupancy rates (BOR) as a metric to understand bed utilization, which is insufficient in capturing the risk of bed shortages. Based on the riskiness index of Aumann and Serrano (2008), we propose the entropic bed shortage metric, which captures more facets of bed shortage risk than traditional metrics such as the occupancy rate, the probability of shortages and expected shortages. We also propose optimization models to control the risk of bed shortages and plan for bed capacity via this metric. These models have linear program re-formulations which can be solved efficiently on a large scale.

## 2 - Cost-effectiveness Analysis of Clinical Management Strategies for Undifferentiated Febrile Illness in the Era of Responsible Antibiotic Use

Zhenhuan Zhang, University of Minnesota, Minneapolis, MN, 55414, United States, Diana Maria Negoescu, Claudia Munoz-Zanzi

Febrile illnesses such as dengue, leptospirosis and scrub typhus have similar symptoms and are often difficult to differentiate without diagnostic tests. If not treated appropriately, patients could experience serious complications. The question of what diagnostic test to use and when to administer antibiotic treatment to avoid misuse of scarce resources and ensure best possible health outcomes remains an open problem. We construct a Markov model of febrile illness progression to assess the cost-effectiveness of fifteen clinical management strategies for diagnosing and treating acute undifferentiated febrile illness in Thailand under different attitudes towards antibiotic use.

## 3 - Data Driven Personalized Treatment Planning for Chronic Diseases

Christof Naumzik, ETH Zurich, Zurich, Switzerland, Stefan Feuerriegel

Medical research has found the progression of chronic diseases to transition between different clinical phases (e.g. acute and stable). These trajectory phases are relevant for clinical practice, since they serve as the basis for providing care and nursing. Yet their correct identification is challenging, as symptoms are only stochastically related to them. We formalize a hidden Markov model with latent states matching the trajectory phases as defined by the Corbin-Strauss trajectory framework. A copula approach is implemented to handle multivariate observations (e.g. pain and disability).

## 4 - A Robust Approach to Study Multiple Treatments: Hierarchical Contrast-specific Propensity Score

Shasha Han, NUS Business School, National University of Singapore, NUS Business School, Biz 2 Building B1, 1 Business Link, Singapore, Singapore, Joel Goh, Fanwen Meng, Donald Rubin

The worldwide rise in number of patients with diabetes and the consequent secondary complications is afflicting human population globally. To study the multiple medications treatment effect for diabetes, we propose a hierarchical contrast-specific propensity score (CSPS) approach. One merit of the approach is that it is robust to misspecification of the functional form of CSPS. The results from diabetes data in Singapore corroborates our theoretical findings. Due to such robustness, the hierarchical CSPS could be influential in causal inference for multiple treatments. Also, the approach charts one of the paths towards personalized medication in healthcare.

## ■ SA61

West Bldg 102C

## Information Provision in Selling Platforms, Health Care and Public Sectors

Sponsored: Manufacturing & Service Oper Mgmt

Sponsored Session

Chair: Shouqiang Wang, The University of Texas at Dallas, Richardson, TX, 75080, United States

## 1 - Conspicuous by Its Absence: Diagnostic Expert Testing under Uncertainty

Tinglong Dai, Johns Hopkins University, 100 International Dr, Baltimore, MD, 21202, United States, Shubhranshu Singh

In many professional services, diagnostic experts may not be able to immediately reach correct diagnoses for their clients' conditions, and often resort to diagnostic testing with cost implications (e.g., money, time, discomfort, or side effect). In this paper, we formulate a diagnostic expert's pathway-selection problem when the peers observe these decisions and form beliefs about the expert's skill level. We find that the high-type expert's optimal diagnostic pathway may entail not performing the test even when it generates a positive surplus. We also show under-testing is the unique pattern allowing the high-type expert to credibly signal her type.

## 2 - Information Design of Time-locked Sales Campaigns for Online Platforms

Can Kucukgul, The University of Texas at Dallas, Richardson, TX, 75080, United States, Ozalp Ozer, Shouqiang Wang

Many online retailing platforms nowadays offer time-locked sales campaigns as an innovative selling mechanism, whereby third-party sellers sell their products at a typically discounted price for a fixed time horizon of pre-specified length. To incentivize purchases, platforms provide some information on up-to-date sales as campaigns progress, in the hope of influencing an upcoming consumer's valuation of products. We propose an easy-to-implement and near optimal information provision strategy for such a time-locked sales campaign. Our policy has important managerial implications, and yields significant profit improvement upon some na ve policies currently implemented in practice.

## 3 - Fast and Slow Learning from Reviews

Ali Makhdoumi, MIT, 77 Massachusetts Ave., 32D-640, Cambridge, MA, 02139, United States

We study the design of rating systems in online platforms. In particular, we consider a model of Bayesian learning from online reviews and characterize the speed of asymptotic learning of the quality of a product. We then characterize the impact of information provision on the speed of learning and identify situations in which providing more information leads to slower learning.

## 4 - Warning Against Recurring Risks: An Information Design Approach

Shouqiang Wang, The University of Texas at Dallas, Naveen Jindal School of Management, 800 W. Campbell Rd, Richardson, TX, 75080, United States, Saed Alizamir, Francis E. De Vericourt

Organizations or government agencies typically emit warning messages to alert relevant stake-holders about potential disastrous events of repetitive nature. Nonetheless, when the adverse event does not materialize, these false alarms affect the agencies' credibility and hence their ability to mobilize timely responses to future threats. Thus, when sounding an alarm, the agencies need to weigh their current ability to elicit immediate actions against the efficacy of their future warning messages. Our research aims to elucidate how to resolve such trade-offs.

## ■ SA62

West Bldg 103A

## Data Mining Applied Paper Finals

Sponsored: Data Mining

Sponsored Session

Chair: Tong Wang, University of Iowa, Iowa City, IA, 52245, United States

Co-Chair: Ramin Moghaddass, University of Miami, Miami, FL.

## 1 - Data Mining Applied Paper Finals

Tong Wang, University of Iowa, Iowa City, IA, USA., Five finalists of 2018 Data Mining Best Paper Awards (Applied Track) will present their work in this session.

## ■ SA63

West Bldg 103B

## Data Analytic to Facilitate Better Decision Making

Sponsored: Data Mining

Sponsored Session

Chair: Roy Jafari Marandi, Cal Poly, 1 Grand Avenue, San Luis Obispo, CA, 93407, United States,

## 1 - Decision-driven Data Analytics: Case Study of Breast Cancer Diagnosis

Roy Jafari Marandi, Mississippi State University, 260 McCain Engineering Buildin, Mississippi, Mississippi State, MS, 39762, United States

This talk focuses on presenting the development and adaptation of data analytic tools that are created or adapted to improve decision-making. The emphasis of this talk is to highlight the efforts and existing research gaps that pertain to improving data analytic techniques to better serve decision-making goals. Breast cancer diagnosis, which is an essential medical decision, will be used as an example and case study to further clarify the presented concepts, techniques, and contributions.

## 2 - Predicting Personnel Fraud

Ekrem Duman, Ozyegin University, Istanbul, Turkey

Predictive analytics is an important tool to drive useful business results from data. However, for successful predictive models one should have enough number of examples for the classes to be predicted. When the number of examples is small, building strong predictive models becomes a very challenging task. In this study we pick up one such problem: predicting the bank personnel which might commit fraud. In order to have a strong enough predictive model, we decided to combine the powers of descriptive and predictive modeling techniques where we developed several descriptive models and used them as input of predictive model at the last stage. The results show that our solution approach perform quite well.

### 3 - Survival Rate Prediction in Cardiac Patients with Heart Transplant or Assisted Devices

Maryam Soltanpour Gharibdousti, Binghamton University, 1120 Murray Hill Road, Vestal, NY, 13850, United States

The survival rate prediction for the organ transplant surgery patients can help to classify patients risk levels and potential post-surgical complications. The research used the data for cardiac patients with either medical assist devices such as Impella and Left Ventricular Assist Devices (LAVD) or heart transplant patients. The significant factors such as demographic information, baseline patient characteristics, baseline hemodynamics, laboratory values, and in-hospital complications can predict the survival rate after the transplant surgery. The data from one of the Organ Procurement Organizations (OPO) in New York state is analyzed using several machine learning algorithms.

## SA64

West Bldg 104A

### Joint Session DM/AI/practice Curated: Urban Big Data Analytics and Mining

Sponsored: Data Mining

Sponsored Session

Chair: Xun Zhou, University of Iowa, Iowa City, Iowa

#### 1 - Predicting Urban Dispersal Events: A Two-stage Framework Through Survival Analysis

Amin Vahedian Khezerlou, University of Iowa, IA, United States

In this work, we focus on predicting unexpected dispersal of people in urban setting, based on taxi pick-up records. Unlike regular taxi pick-up patterns, which are highly regular and predictable, the irregular dispersal events do not follow an obvious pattern and are challenging to predict. Such predictions can be used to better plan public safety and traffic management, as well as business profit. We propose a supervised learning framework which takes advantage of survival analysis to infer the event time, and also predict the event volume. We use a public dataset of taxi records for evaluations. We outperform baseline methods by a significant margin.

#### 2 - Multi-Frequency Convolutional LSTM for Crime Prediction

Maryam Rahmani Moghaddam, University of Iowa, Iowa City, IA, United States

The crime prediction problem aims at predicting the location and time of the future crimes. This problem is challenging due to the spatial and temporal sparsity of the crimes. In this work, we propose a Multi-Frequency Convolutional LSTM model, which is an ensemble of multiple convolutional lstm models trained by subsets of historical data with varying sampling intervals to capture the multi-frequency patterns of crimes. The combined output of these models using a convolutional neural network is further combined with the historical map through a spatial regression. We test our model on 5 years (Feb 2015-Feb 2017) of burglaries (23797 reports) in Portland, Oregon provided by the Portland Police Bureau and evaluate the PAI and PEI. We compare the proposed model with baseline methods static-map and Self-Exciting Point Process.

#### 3 - A Holistic Solution for Connected Smart City with Good Environmental Health, Traffic and Energy

Sheela Siddappa, Bosch, Bengaluru, India

Traffic Management is very important aspect towards smart city. As a solution towards smart city, this work concentrates on multiple aspects like 1) IOT based systems adapting Deep Learning and Machine Learning Techniques to accurately identify vehicles that violate traffic rules 2) Estimate the probability of a parking space being available in a locality 45 mins in advance and update with time 3) Estimate the impact of traffic realignment on the environment and iterate accordingly. Overall the solution aims towards a connected city and bring a balance between the environmental health and comfort towards traffic movement and rules in a holistic view.

## SA65

West Bldg 104B

### Big Data Science

Sponsored: Data Mining

Sponsored Session

Chair: Tae Hun Kim, Michigan State University, Eli Broad College of Business, 632 Bogue Street, East Lansing, MI, 48824, United States

#### 1 - Analysis of the Resilience of Public Transportation System Based on Energy Cost of Passengers

Xiongfei Lai, Dr., Tongji University, No. 4800, Cao'an Road, Shanghai, 201804, China, Jing Teng, Lu Ling

Based on field experiments, this paper proposes a calculation method for public transportation service resilience based on the energy cost of passengers. This

method utilizes the heart rate, acceleration and speed data automatically collected by the experimenters when they are walking in subway transfer stations, fits these data to Physical Activity Intensity and uses it as the index of travel energy cost. Subsequently, the accuracy, theoretical and practical prospect of this method are verified by the transfer passenger data of Beijing Subway Line 1 and Line 2 in May, 2017. The results show that the service resilience calculation method can accurately perceive the change of system service efficiency and its recovery ability according to different travel demands of the passengers. At the same time, the method uses automatic data collection to analyze, improves its accuracy and analysis adaptability compared with the traditional analysis methods.

#### 2 - Does User Contribution Enhance Welfare? The Effectiveness of User-crowdsourced Content in Relieving Urban Traffic Congestion

Tae Hun Kim, Baylor University, Waco, TX, 76798, United States, Chenhui Guo, Anjana Susarla, Vallabh Sambamurthy

In a mobile virtual community, Waze app users generates primary information (via alerts), follow-up feedback (via comments), and collective confirmation (via thumbs-up). We examine whether and how the user-crowdsourced content generates welfare by relieving traffic jams in New York City. Spatial panel data models are applied to estimating welfare value with large-scale data on behaviors and locations of users. Based on the results, user contribution reduces traffic congestion duration. A welfare analysis estimates that user contribution saves 2.28% of annual congestion cost per driver in the city. The welfare value shows that user contribution is effective in saving social and economic costs.

## SA66

West Bldg 105A

### Artificial Intelligence in Big Data

Sponsored: Artificial Intelligence

Sponsored Session

Chair: Jiaheng Xie, University of Arizona, Tucson, AZ, 85721, United States

#### 1 - Visual Social Media Analytics: Impact of Medical Knowledge on User Engagement

Xiao Liu, University of Utah, UT, United States

Video sharing social media sites, such as YouTube, that host videos providing information on the pathogenesis, diagnosis, treatments, and prevention of various conditions can be an effective way to understand medical knowledge and in managing chronic conditions through patient self-care. However, due to the heterogeneity of the content quality and content helpfulness on visual social media, healthcare providers and government agencies have expressed concerns about the quality and reliability of such information. There have been relatively few studies that have identified interventions to increase the ease with which patients can find helpful health information. We propose an interdisciplinary lens that synthesizes deep learning methods with themes emphasized in Information Systems (IS) research and research on healthcare informatics. Using a bidirectional long short-term memory (BLSTM) method, we extract medical terminology from videos. We annotate videos using inputs from domain experts and build a logistic regression based classifier to categorize videos based on whether they encode a high degree of medical knowledge or not. We identify distinct types of user engagement with videos on YouTube using a principal components analysis (PCA) approach: user dissonance, popularity based engagement, and relevance based engagement. We find that medical knowledge encoded in videos matters to patient engagement; however, popularity-based indicators of engagement indicate that videos that score high on medical knowledge encoded in videos, are actually less popular than those that are not. We conduct robustness checks using a convolutional neural network (CNN) to detect the presence of medical objects in a video. We find that medical terminology embedded in textual data is more salient to an assessment of medical knowledge encoded in a video, rather than image analytics. Our results suggest that healthcare practitioners and policymakers need a nuanced understanding of how users engage with medical knowledge in video format, which has implications for the role of videos and visual social media in bridging the health literacy gap and in enabling self-care of chronic conditions.

#### 2 - Are More Diverse Crowds Smarter?

Jiayu Yao, Georgia Institute of Technology, Atlanta, GA, United States, Qiang Gao, Mingfeng Lin

Does the diversity increase the wisdom of crowds? We examine the value of diversity in crowds within a market setting, specifically, the online financial market, utilizing a natural experiment on Prosper.com.



### 3 - Diversity Based Link Recommendation Algorithm

Kexin Yin, University of Delaware, 1020 Wharton Drive,  
Newark, DE, 19711, United States

By 2018, more than 4 billion people are reported using the internet all over the world, while more than 3 billion people are actively using social media. Social network sites are playing important roles in this information era. Link recommendation, the core technique targeting to help users establish a good friendship network, attracts significant attentions from both industry and academic researchers. However, friends recommended by an existing method are generally homogeneous in terms of their backgrounds, e.g. location or current university, because existing methods recommend friends with similar backgrounds or interests or sharing many common friends with a user. Serving as an important information source for users, social networks can perform better if they can introduce diversity in link recommendation. Improving social network diversity could increase the possibility for users to be connected with different information communities, thus gaining users social capital and competence. Because different users may have different preference of diversity when they make friends, and people can have different diversity preference on different dimensions of user background, link recommendation can be made to have different diversity level according to user's diversity preference on each user background dimension. In this presentation, multi-dimensional diversity preference is introduced as a new factor in link recommendation, and a new link recommendation problem, namely diversity preference-aware link recommendation problem is defined and proved to be a NP-hard problem. An efficient heuristic solution method will be developed based on the heuristic algorithm of binary quadratic programming and empirically tested with a real social network data set from Google+..

### 4 - Using Long Short-Term Memory to Predict Hospital Readmission

Jiaheng Xie, University of Arizona, 1130 E. Helen Street, Tucson,  
AZ, 85721, United States

Hospital readmission refers to the situation where a patient is re-hospitalized with the same primary diagnosis within a specific time interval after discharge. Hospital readmission causes \$26 billion preventable expenses to the U.S. health systems annually and often indicates suboptimal patient care. To alleviate those severe financial and health consequences, it is crucial to proactively predict patients' readmission risk. Such prediction is challenging because the evolution of medical events (illness trajectory) is dynamic and complex. The state-of-the-art studies apply statistical models which assume homogeneity among all patients and use static predictors in a period, failing to consider patients' heterogeneous illness trajectories. Our approach ð TADEL (Trajectory-BASED DEep Learning) ð is motivated to tackle the problems with the existing approaches by capturing various illness trajectories and accounting for patient heterogeneity. We evaluated TADEL on a five-year national Medicare claims dataset including 3.6 million patients per year over all hospitals in the United States, reaching an F1 score of 0.867 and an AUC of 0.884. Our approach significantly outperforms all the state-of-the-art methods. Our findings suggest that health status factors and insurance coverage are important predictors for readmission. This study contributes to IS literature and analytical methodology by formulating the trajectory-based readmission prediction problem and developing a novel deep-learning-based readmission risk prediction framework. From a health IT perspective, this research delivers implementable methods to assess patients' readmission risk and take early interventions to avoid potential negative consequences.

## ■ SA67

West Bldg 105B

### Joint Session ISS/Smart Cities: Economics of Smart Cities

Sponsored: Information Systems

Sponsored Session

Chair: Beibei Li, Carnegie Mellon University, Pittsburgh, PA, 15213, United States

#### 1 - Learning Individual Behavior Using Sensor Data: The Case of GPS Traces and Taxi Drivers

Beibei Li, Carnegie Mellon University, 5000 Forbes Ave, Hamburg Hall 3026, Pittsburgh, PA, 15213, United States

Abstract not available.

#### 2 - Peer-to-peer Transportation Platforms and Local Consumer Mobility

Zhe Zhang, Carnegie Mellon University, 4800 Forbes Avenue, Pittsburgh, PA, 15213, United States

Abstract not available.

#### 3 - Pricing Efficiently in Designed Markets: Evidence from Ride-Sharing

John Horton, New York University, New York, NY, United States,  
Jonathan V. Hall, Daniel T. Knoepfle

In many designed markets, the platform eliminates price dispersion by setting the product market price, yet still allows supply-side free entry and exit. We explore the equilibrium of such markets, using data from Uber. Following price increases,

drivers make more money per trip and—and initially more per hour-worked—and as a result, work more hours. However, this increase in hours-worked has a business stealing effect, with drivers spending a smaller fraction of hours-worked with paying customers, eventually bringing the hourly earnings rate back close to its previous level. The resulting higher fare/lower productivity equilibrium is generally inefficient.

### 4 - The Value of Time: A High-Frequency Analysis of Ride-Hail Auctions

Nick Buchholz, Princeton University, NJ, United States

We use detailed consumer choice data from a large ride-hailing application to study consumer valuations of time. This application offers a unique mechanism that allows taxi drivers in the Czech Republic to bid on trips, and allows consumers to choose between a set of characteristics of a ride: price, waiting time (based on the distance from consumers to each available taxi), car type and driver ratings. We observe the tradeoffs consumers face between prices and waiting times across 1.9M ride requests and 5M bids, as well as their ultimate selection. We leverage rich variation in bids and customer choices to directly measure consumer willingness-to-pay for time savings and decompose it further by time-of-day and location. Baseline estimates from Prague show the value of waiting to exceed median wages; from \$0.40 per minute in peak weekday morning hours, to \$0.05 per minute in off-peak weekend hours. Waiting times are important to explain customers' choices, on average accounting for 13.7 percent of total valuation. We use our preference estimates to quantify the welfare benefits of offering a menu of time and price options. Our results show that a flexible menu of waiting time and choices improves welfare by up to 48 percent over a more standard dispatch mechanism.

## ■ SA68

West Bldg 105C

### QSR Best Student Paper Award

Sponsored: Quality, Statistics and Reliability

Sponsored Session

Chair: Youngjun Choe, University of Washington, Seattle, WA, 98105, United States

Co-Chair: Matthew Plumlee, Northwestern University, Northwestern University, Evanston, IL, 60208, United States

#### 1 - Monitoring for Changes in the Nature of Stochastic Textured Surfaces

Anh Tuan Bui, Northwestern University, Technological Institute 2145 Sheridan Road, Room C210, Evanston, IL, 60208, United States

This work monitored for changes in the nature of stochastic textured surfaces without requiring prior knowledge of the changes. We used supervised learning to characterize the joint distribution of surface image pixels. Our monitoring statistic was based on likelihood-ratio principles. We demonstrated the approach with textile and simulation examples.

#### 2 - Predictive Comparisons for Screening and Interpreting Inputs in Machine Learning

Raquel Ferreira, Purdue University, West Lafayette, IN, 47907, United States

A methodology based on predictive comparisons is specified to identify important inputs and interpret their associations with an outcome that are obtained via a machine learning algorithm. New predictive measures are constructed to perform input screening, and interpret conditional and two-way interactions of inputs.

#### 3 - Scan B-Statistic for Kernel Change-Point Detection

Shuang Li, Georgia Institute of Technology, Atlanta, GA, United States

Detecting the emergence of an abrupt change-point is a classic problem in quality control, statistics and machine learning. In this paper, we propose a computationally efficient kernel-based nonparametric statistic for change-point detection, which enjoys fewer assumptions on the distributions than the parametric approaches and can handle high-dimensional data. A novel theoretical approximation of the tail probability of these statistics is proposed, which provides a convenient way to find the detection thresholds for both offline and online cases. We show that our methods perform well on both synthetic data and real data.

#### 4 - Scalable Robust Monitoring of Large-Scale Data Streams

Ruizhi Zhang, Georgia Institute of Technology, Atlanta, GA, United States

Online monitoring large-scale data streams has many important applications. However, it is non-trivial to develop efficient schemes due to three challenges: robustness, sparsity and computation. To tackle these challenges, we propose an efficient, robust and scalable monitoring scheme. Asymptotic analysis and extensive numerical simulations illustrate the usefulness of our proposed scheme.

## ■ SA69

West Bldg 106A

### Joint Session QSR/Practice Curated: Data Analytics in Healthcare Applications

Sponsored: Quality, Statistics and Reliability

Sponsored Session

Chair: Dongping Du, Texas Tech University, Lubbock, TX, 79409, United States

#### 1 - Network-based Analysis of Multivariate Sensory Data for Real-time Monitoring of Cardiac Patients

Chen Kan, University of Texas at Arlington, Arlington, TX, United States

In this paper, a new network model is developed to integrate multivariate sensory data for real-time detection of abnormal cardiac patterns. Each cycle of the high-dimensional signal is mapped as a weighted network. Structural variations among networks are characterized by optimal network alignment, which are then incorporated into an exponentially weighted moving average control chart for in-situ monitoring. Experimental results show that the proposed network model effectively and efficiently captures incipient changes of cardiac activity for the early identification of disease patterns.

#### 2 - Atrial Fibrillation Source Identification Using Multinomial Distribution and Maximum Likelihood Estimation

Dongping Du, Texas Tech University, 2500 Broadway, P.O. Box 43061, Lubbock, TX, 79409, United States, Amirhossein Koneshloo

Atrial Fibrillation (AF) is the most common sustained cardiac rhythm disorder. Identifying AF triggers is essential for efficient treatment design. However, due to the uncertainty and randomness associated with electrical wave propagation, determining the trigger locations is challenging. In this study, we develop a robust probabilistic method to track the electrical wave conduction in AF in the presence of uncertainty. The method provides confidence regions that successfully capture AF sources. The confidence bounds can be valuable references for AF ablation design and planning.

#### 3 - A Mixed Effects Multi-task Learning Model for Parkinson's Disease Monitoring Using Smartphones

Hyunsoo Yoon, Arizona State University, 699 S. Mill Ave, Tempe, AZ, United States, Jing Li

Built-in sensors in smartphones can conveniently collect the activities of PD patients. The cost-effectiveness of this method allows patient conditions to be assessed frequently for more effective treatment. However, due to patient heterogeneity, patient-specific models are needed but face the challenge of limited data regarding the Unified PD rating Scale representing disease severity. We propose a multi-task learning approach, MEMTL, which can utilize both general population and patient-specific patterns to improve prediction performance. The unique features of MEMTL include detection of early signs of PD and accurate prediction of PD progression.

#### 4 - Subspace Learning and Representation of Dynamic Coordination Pattern Across Multiple Joints During Movement for Chronic Ankle Instability

Shaodi Qian, Northeastern University, Boston, MA, 02115, United States, Sheng-Che Yen, Eric Folmar, Chun-An Chou

Ankle sprains and instability are major public health concerns. Up to 70% of individuals don't fully recover from a single ankle sprain and develop chronic ankle instability (CAI). The diagnosis of CAI is usually based on self-report rather than objective biomechanical measures. In this study, we propose a new analytics method to identify discriminative patterns in the coordination among bilateral hip, knee, and ankle joints between individuals with CAI and health cohorts. A subspace learning algorithm is developed to estimate the multi-joint coordination patterns. The computational results show >80% classification accuracy with the identified patterns using a SVM classifier.

## ■ SA70

West Bldg 106B

### Joint session QSR/DM: Challenges and Novel Solutions in Multi-Source Data Integration

Sponsored: Quality, Statistics and Reliability

Sponsored Session

Chair: Ying Lin

#### 1 - Personalized Treatment Monitoring and Switching Policies for Chronic Depression

Mutita Siriruchatanon, University of Washington, Seattle, WA, United States, Shan Liu

To achieve better health outcomes, early detection of ineffective treatment plays a key role in developing optimal treatment plans. We formulated a personalized treatment monitoring and switching problem for chronic depression as a Markov decision process, and estimated the individual treatment effects on disease transitions. Considering the tradeoff between exploration and exploitation in solving the MDP, optimal treatment policies were obtained and analyzed using simulated data. This work is a starting point to enable optimal depression treatment selection using a decision support system.

#### 2 - Detect Depression from Communication: How Computer Vision, Signal Processing, and Sentiment Analysis Join Forces

Aven Samareh, University of Washington, 4324 8th ave NE, D7, Seattle, WA, 98105, United States, Yan Jin, Zhangyang Wang, Xiangyu Chang, Shuai Huang

Depression will leave recognizable markers in patient's vocal acoustic, linguistic, and facial patterns, all of which have demonstrated increasing promise on evaluating and predicting patient's mental condition in a more objective way. We developed a multi-modality prediction model to combine the audio, video, and text modalities, to identify the biomarkers that are predictive of depression with consideration of gender differences. We identified promising biomarkers from successive search on feature extraction analysis for each modality.

#### 3 - Forecasting the Demand for Mobile Clinic Service Based on Demographic and Clinic Data

Bilal Majeed, University of Houston, Houston, TX, 77054, United States, Jiming Peng, Ying Lin

Demand forecasting plays an important role in the deployment of mobile clinic services as it can help a mobile clinic to maximize its coverage under limited resource. In this talk, we present a new forecasting model to predict the delinquency rate in census tracts based on the clinic and the demographic data. For this, we first develop some associations between the delinquency data in census tracts and school zones. Then we combine semi-supervised learning and convex optimization to build up a forecasting model for the delinquency rates in all the census tracts. A case study in Harris County will be reported to demonstrate the efficacy of the new model and technique.

## ■ SA71

West Bldg 106C

### Joint Session ICS/IOS-Uncertain: Stochastic and Distributionally Robust Optimization

Sponsored: Computing

Sponsored Session

Chair: Hamed Rahimian, Northwestern University, 2145 Sheridan Rd, Evanston, IL, 6208, United States

#### 1 - Distributionally Robust TSP with Wasserstein Distance

Mehdi Behrooz, Northeastern University, Department of Mech. & Ind. Engineering, 334 Snell Engineering Center, Boston, MA, 02115, United States, John Gunnar Carlsson, Kresimir Mihic

Motivated by a districting problem in multi-vehicle routing, we consider a distributionally robust version of the travelling salesman problem in which we compute the worst-case spatial distribution of demand against all distributions whose Wasserstein distance to an observed demand distribution is bounded from above. This allows us to circumvent common overestimation that arises when other procedures are used, such as fixing the center of mass and the covariance matrix of the distribution. Numerical experiments confirm that our new approach is useful when used in a decision support tool for dividing a territory into service districts for a fleet of vehicles when limited data is available.

#### 2 - Distributionally Robust Optimization with Chance Constraints Using Wasserstein Metric

Ran Ji, George Mason University, 4400 University Dr. MS 4A6, Fairfax, VA, 22030, United States, Miguel Lejeune

We study distributionally robust chance-constrained optimization problems DRCCP with Wasserstein metric under two types of uncertainties (uncertain probabilities and continuum of realizations). For the case of uncertain probabilities (resp. continuum of realizations), we propose a set of deterministic mixed-integer linear programming (resp. second-order cone programming) inequalities to reformulate DRCCP. We transform the chance constraints to the expectation ones via indicator function, then leverage the convex duality to reformulate the expectation constraints under Wasserstein ambiguity set. We derive valid inequalities to enhance the computational efficiency.

#### 3 - Two-stage Distributionally Robust Mixed Integer Program

Manish Bansal, Virginia Tech., 227 Durham Hall, 1145 Perry Street, Blacksburg, VA, 24060, United States

In this talk, we present our recent advances for solving two-stage distributionally robust mixed integer program and its variants.

## ■ SA72

West Bldg 211A

**Healthcare Delivery Policy and Implementation**

Sponsored: Manufacturing &amp; Service Oper Mgmt/Healthcare Operations

Sponsored Session

Chair: Shima Nassiri, University of Michigan, Ann Arbor, MI, 48109, United States

**1 - Outcomes-based Reimbursement Policies for Chronic Care Pathways**

Sasa Zorc, INSEAD, 1 Ayer Rajah Avenue, PhD Office, Singapore, 138676, Singapore, Stephen E. Chick, Sameer Hasija

We develop an outcomes-based model of contracting in care for chronic patients, using data from United Kingdom's NHS. The government contracts with healthcare providers in effort to maximise population health minus the cost. We consider the decision of whether to contract with individual healthcare providers or groups of such providers, as well as which contract type to use. Individual contracts fail to provide the desired incentives if providers under such contracts cooperate (collusion), however so do group contracts if group members fail to coordinate (free-riding). We demonstrate that individual outcomes-adjusted capitation contracts are the most resistant to these adverse effects.

**2 - Predicting with Proxies: Improving Medical Risk Scores**

Hamsa Sridhar Bastani, Wharton School, Philadelphia, PA, United States

Risk scores are often used by providers to target interventions, and by payers to estimate costs. However, such scores may not transfer well from one healthcare provider to another due to differences in physician behavior, medical coding practices, and patient risk factors. On the other hand, developing a different risk score for each provider may be infeasible due to data scarcity. We present a new technique for adapting an existing risk score to a new provider by learning important biases specific to that provider. We evaluate our technique on a diabetes prediction task and demonstrate both improved predictive performance as well as insights into underlying differences between providers.

**3 - Outcome-based Pricing for Pharmaceuticals**

Elodie Adida, University of California - Riverside, School of Business Administration, 900 University Avenue, Riverside, CA, 92521, United States

We study the effect of outcome-based pricing for pharmaceuticals. Under this payment scheme, the pharmaceutical firm is paid only when the drug treatment achieves a pre-specified goal. We consider heterogeneous, price-sensitive, risk-averse patients, a payer, and a pharmaceutical firm producing a drug with uncertain effectiveness. We find that outcome-based pricing is unlikely to solve the issues of high drug prices and high payer expenditures. However, supplementing outcome-based pricing with a transfer payment between firm and payer can make patients, payer and firm better off than under uniform pricing.

**4 - The Price of Simplicity in Personalized Prostate Cancer Screening Strategies**

John Silberholz, University of Michigan, Ross School of Business

Patient preferences for different health states can significantly impact their best course of action in screening for diseases like prostate cancer. Patients with a relatively small disutility for treatment side effects might benefit from aggressive screening, while others might benefit from less aggressive screening or no screening at all. In this work, we use a mathematical model to quantify the benefit of fully personalized prostate cancer screening versus a one-size-fits-all strategy. Further, we identify simpler, more interpretable personalized screening strategies that could be easier to implement in practice, and we quantify the price of this simplicity in strategies.

## ■ SA73

West Bldg 211B

**JFIG Panel Discussion: Best Practices in Reviewing Papers**

Sponsored: Junior Faculty JFIG

Sponsored Session

Chair: Canan Gunes Corlu, Boston University, Boston, MA, 02215, United States

Co-Chair: Gokce Palak, Shenandoah University, Winchester, VA, 22601, United States

**1 - JFIG Panel Discussion: Best Practices in Reviewing Papers**

Canan Gunes Corlu, Boston University, 808 Commonwealth Avenue, Boston, MA, 02215, United States

Past and current associate editors will provide advice about reviewing papers from

responding to an invitation to writing the report.

**Panelists**

Dashi Singham, Naval Postgraduate School, 1411 Cunningham Road, Operations Research Department, Monterey, CA, 93943, United States

Robert Shumsky, Professor, Tuck School, Dartmouth, Tuck School of Business, 100 Tuck Hall, Hanover, NH, 03755, United States

Burak Eksioglu, Clemson University, Department of Industrial Engineering, 272 Freeman Hall, Clemson, SC, 29634, United States

## ■ SA74

West Bldg 212A

**Recent Algorithmic Advances on Multi-objective Integer Programming**

Sponsored: Multiple Criteria Decision Making

Sponsored Session

Chair: Hadi Charkhgard, University of South Florida, Tampa, FL, 33620-5350, United States

**1 - OOES.jl: A Julia Package for Optimizing a Linear Function Over the Set of Efficient Solutions for Bi-objective Mixed Integer Linear Programming**

Alvaro Sierra-Altamiranda, University of South Florida, Tampa, FL, United States, Hadi Charkhgard

We present 'OOES.jl', a flexible package for optimizing a linear function over the set of efficient solutions for bi-objective mixed integer linear programs. The proposed framework extends our recent algorithm, by adding two main characteristics: (1) The package allows using any single-objective mixed integer programming solver supported by 'MathProgBase.jl'; (2) The algorithm works under multiprocessing environments by exploiting parallelization. An extensive computational study evaluates the performance of the package versus previous C++ implementation, the performance of parallelization and provides a comparison between different solvers available in the market.

**2 - A Branch-and-Bound Algorithm for a Class of Mixed Integer Linear Maximum Multiplicative Programs: A Multi-objective Optimization Approach**

Payman Ghasemi Saghand, FL, United States, Hadi Charkhgard, Changhyun Kwon

We present a linear programming based branch-and-bound algorithm for a class of mixed integer optimization problems with a bi-linear objective function and linear constraints. These problems can be viewed as a special case of optimization over the efficient set. It is known that without integer variables, such problems can be transformed into a Second-Order Cone Program (SOCP) and be solved by CPLEX SOCP. Also, such problems can be solved faster by a linear programming based algorithm. In this study, we embed that algorithm in an effective branch-and-bound framework to solve mixed integer instances. An extensive computational study shows that the proposed algorithm outperforms CPLEX SOCP solver.

**3 - MSEA-1.0: A Multi-Stage Exact Algorithm for Bi-objective Pure Integer Linear Programming in Julia**

Hadi Charkhgard, PhD, The University of South Florida, Tampa, FL, United States, Aritra Pal

We present a new exact method for bi-objective pure integer linear programming, the so-called Multi-Stage Exact Algorithm (MSEA). The method combines several existing exact and approximate algorithms in the literature to compute the entire nondominated frontier of any bi-objective pure integer linear program. Each algorithm available in MSEA has multiple versions in the literature. Hence, the main contribution of our research is developing a unified framework for all these versions in MSEA. The package supports execution on multiple processors and users (if interested) can easily customize the package for their specific problems.

**4 - Enabling Energy Storage Sharing among Multiple Independent Users: A Multi-objective Optimization Approach**

Rui Dai, University of South Florida, Tampa, FL, United States, Hadi Charkhgard

Energy storage sharing should be coordinated in a proper way to ensure the fairness and efficiency when allowing users exchange their stored energy. To address this challenge, this work proposes a multi-objective optimization based sharing strategy to operate an energy storage system shared by multiple independent users. In order to guarantee the fairness in the exchange of stored energy, the payoff for the user transferring their stored energy to other users is calculated. This strategy is formulated as a Nash bargaining problem, and solved through a multi-objective optimization approach. In addition, piecewise McCormick relaxation is adopted to linearize the existing bilinear terms.



## ■ SA75

West Bldg 212B

### Joint Session MAS/Practice Curated: Cybersecurity Analysis and Applications I

Joint Session

Chair: Paul L. Goethals, United States Military Academy, West Point, NY, 10996, United States

#### 1 - Quantum Correlation Sets and the Limits of Quantum Communication

Travis Russell, PhD, Army Cyber Institute, West Point, NY, 10996, United States

A quantum correlation is a kind of probability distribution that can be achieved with quantum technology but cannot be achieved by classical probabilistic means. The study of quantum correlations goes back to debates between Albert Einstein and his contemporaries during the formative years of quantum mechanics, yet there are many questions about quantum correlations that remain unanswered to this day. In this talk, we introduce the idea of quantum correlations and discuss some connections with positive semidefinite programming, operator algebras and cyber security.

#### 2 - Cyber Attacks Models Based on Weighted Rooted Trees

Elie Alhajjar, Army Cyber Institute, West Point, NY, 10996, United States

In recent years, Agnarsson et al. defined a rooted tree model for cyber-security systems based on defense-in-depth and layered-security approaches, as many systems do. In the model, the concepts of penetration cost and acquisition gain are introduced and decision and optimization problems are formulated. In this talk, we look at the problem of storing targets via the intuition that high-value targets should be deeper in the system and outer layers should have higher penetration costs. Moreover, we address the possibility of repositioning targets periodically and how it affects the dynamics of the network.

#### 3 - Locating Arrays: A New Experimental Design for Complex Engineered Systems

Violet Syrotiuk, PhD, Arizona State University, Tempe, AZ, United States

Screening experiments are used to identify significant factors and interactions on a response. Traditional experimental designs for screening in complex engineered systems requires either restricting the factors considered, which automatically restricts the interactions, or restricting interest to main effects, which fails to consider interactions. To address this problem we propose a locating array (LA) as a screening design. LAs exhibit logarithmic growth in the number of factors allowing an order of magnitude more factors in experimentation than traditional approaches. We apply an LA for screening responses in an experiment on w-iLab.t, a wireless network testbed in Belgium.

#### 4 - Modeling in Cyberspace: Accounting for the Human Dimension

Paul L. Goethals, United States Military Academy, 66-B Schofield Place, West Point, NY, 10996, United States, Natalie Scala

It is now widely recognized that a large number of our cybersecurity vulnerabilities are attributed to human error of some kind. The models that account for the human dimension, however, are somewhat sparse in the cyberspace literature. This talk will outline some of the existing research lines of effort and discuss potential opportunities for future research in this area.

## ■ SA76

West Bldg 212C

### Design and Control of Manufacturing Systems

Emerging Topic: Design and Control of Manufacturing Systems

Emerging Topic Session

Chair: Yunyi Kang, Arizona State University, Tempe, AZ, 85281, United States

#### 1 - Real-time Manufacturing System Performance Evaluation using Machine Degradation Signals

Yunyi Kang, Arizona State University, 1850 E. Hayden Lane, Apt 207, Tempe, AZ, 85281, United States, Hao Yan, Feng Ju

Evaluating and predicting real-time system performance is important while challenging for modern manufacturing practitioners. With the help of sensor technology, real-time system conditions can be measured and collected. In this work, we build up a Markovian model to evaluate the instant production performance, given the machine degradation signals, in two-machine-and-one-buffer systems. Phase-type distributions are used to mimic the machine operational time distributions based on signal information. A case study is provided to show that such a model can be applied effectively in practice.

#### 2 - Conic Reformulations of Production Planning Models with Clearing Functions

Karthick Gopalswamy, North Carolina State University, 3000 Kings Court, Unit G, Raleigh, NC, 27606, United States, Reha Uzsoy

We consider the problem of planning the releases into a production system to meet demand in a near-optimal manner. Clearing function models that capture the queuing behavior of production systems under congestion are considered. We provide a conic reformulation of the non-linear constraints in the multi-product problem and provide computational experiments on the solution quality of different model in comparison to traditional LP models and a linear approximation of the non-linear model.

#### 3 - Approximations for Dynamic Multi-class Manufacturing Systems with Priorities and Finite Buffers

Girish Jampani Hanumantha, Arizona State University, Tempe, AZ, 85281, United States, Ronald G. Askin

Steady-state queueing models are commonly used as a performance evaluation component in aggregate planning. However, with shortened product introduction and life cycles and constantly evolving customer preferences the assumption of stationary demand processes is no longer reasonable. Nonstationary demand processes capture the dynamic nature of modern manufacturing systems well. We present computationally efficient numerical approximations for dynamic manufacturing systems with part priorities and finite buffers. The performance of these approximations is tested for practically sized instances.

#### 4 - Q-learning Based Overhead Transport (OHT) Routing Algorithm for Massive Vehicle Control

Young Jae Jang, KAIST, Department of Industrial and Systems Engineer, 291 Daehakro, Yuseong-Gu, Daejeon, 34141, Korea, Republic of, Illhoe Hwang

The Overhead Hoist Transport (OHT) is a class of automated material handling system (AMHS) consisting of automated vehicles operating on a network of guideways or specially designed rails. This OHT is widely used in semiconductor fabs and modern high-tech manufacturing production lines. One of the challenges in operating OHT based AMHS for a large scale production line is the development of a routing algorithm controlling massive number of vehicles. We introduce AI based algorithm, Q-learning routing, which effectively control OHT system which consists of more than 500 vehicles. The performance of the algorithm is compared to conventional optimization algorithms.

## ■ SA77

West Bldg 213A

### Challenges and Strategies in Humanitarian Operations

Sponsored: Public Sector OR

Sponsored Session

Chair: Seyma Guven-Kocak, Georgia Institute of Technology, Atlanta, GA, 30340, United States

Co-Chair: Pinar Keskinocak, Georgia Institute of Technology, Atlanta, GA, 30332, United States

#### 1 - Nonprofit Operations: Challenges and Strategies

Gemma Berenguer, Purdue University, 1020 Happy Hollow Rd, West Lafayette, IN, 47906, United States

In this talk I will provide a definition of nonprofit operations and I will give an overview of this field of Operations Management (OM). I will examine the objectives, major actors and major activities of nonprofit operations and I will identify the major challenges and strategies to address the challenges. A specific analysis of the most relevant applied areas and their unique challenges will also be provided.

#### 2 - Competition Over Funding Resources in Humanitarian Operations

Arian Aflaki, University of Pittsburgh, Pittsburgh, PA, United States, Alfonso J. Pedraza-Martinez

We study the optimal funding strategy of Humanitarian Organizations (HOs) in the presence of control seeking donors. We find that monopolist HOs can ask for control over donations to improve their operational efficiency; however, competition between HOs limits their ability to collect non-earmarked donations and contributes to lower operational efficiency as well as higher fundraising costs.

### 3 - The Facts on the Ground: Using Simulation to Understand Policies in Humanitarian Fleet Management

Liyi Gu, University of Maryland, Van Munching Hall, College Park, MD, 20742, United States, Ilya O. Ryzhov, Mahyar Eftekhari

Humanitarian field managers are known to lack systematic guidance in decision making and often rely on their intuition. In this work we develop empirical and stochastic models of humanitarian fleet management, on top of which we build a simulator that evaluates intuitive policies that may be used by field managers. We empirically estimate demands (mission distances) and vehicle operational costs using data from a large international humanitarian organization, and evaluate the acquisition, assignment, and disposition of vehicles in field operations. The simulation results provide insight to why managers make decisions the way they do, and could lead to improved policy recommendations.

### 4 - Scale vs. Impact. Resource Allocation Strategies for Family Planning Outreach

Harwin de Vries, INSEAD, Boulevard de Constance, Fontainebleau, 77210, France, Lisanne Van Rijn, Kim Leliveld, Luk N. Van Wassenhove

We study an organization deploying over 500 mobile outreach teams to bring family planning services to hard to reach communities. Major objectives are to maximize utilization (scale) and to reach target populations like young and poor people (impact). We discuss how operations affect scale and impact, trade-offs, models, and implications.

## ■ SA78

West Bldg 213B

### Joint Session TSL-FAC/SOLA: Random Stow Strategies in Warehousing

Sponsored: Location Analysis

Sponsored Session

Chair: John Gunnar Carlsson, University of Southern California, Los Angeles, 90089, United States

#### 1 - A Velocity-based Stowage Policy for a Semi-automated Fulfillment System

Stephen C. Graves, Massachusetts Institute of Technology, E62-579, 77 Massachusetts Avenue, Cambridge, MA, 02139-4307, United States, Amy Liu

Online retail fulfillment is increasingly performed by semi-automated systems in which inventory is stored in mobile pods that are moved by robotic drives. The stowage decision decides on what pods to store what inventory. We examine the impact of velocity-based stowage policies on the operational performance of the fulfillment system. In particular we model a stowage policy in which received units are categorized as being either fast or slow, and then characterize the impact of velocity-based stowage on the travel distance for the robotic drives. We find that such policies can substantially reduce the travel distance, which reduces the number of drives required for a given system throughput level.

#### 2 - Man vs Machine in Warehouse Picking

Gerard P. Cachon, University of Pennsylvania, 3730 Walnut St, Philadelphia, PA, 19104, United States, Omar Besbes

We compare warehouse pick operations performed the traditional way (with a human) against picking with robots (e.g., Kiva systems). We are interested in how these different systems scale and under what conditions one outperforms the other.

#### 3 - Random Stow and the Generalized Travelling Salesman Problem

John Gunnar Carlsson, University of Southern California, 3750 McClintock Avenue, Los Angeles, CA, 90089, United States

The generalized travelling salesman problem is a variation of the traditional TSP in which one is given a collection of sets of points and one seeks a tour of minimal length that visits one member each set. The GTSP is fundamentally important in studying randomized strategies in warehouses, in which one stores a stock keeping unit (SKU) in any available location (as opposed to designating specific regions of the warehouse for different SKUs). We derive asymptotic bounds for the length of a GTSP tour under various assumptions on the magnitude of demand and its distribution.

#### 4 - Fast Solutions for the Dynamic Item Stocking Problem in Amazon Class Online Order Fulfillment Warehouses

Sanchoy Das, Professor of Industrial Engineering, New Jersey Institute of Technology, University Heights, Newark, NJ, 07102, United States, Jingran Zhang, Sevilya Onal

Amazon class online order fulfillment warehouses use an explosive storage policy, whereby the same item is stocked simultaneously in many bin locations anywhere in the warehouse. The stocking objective is to disperse incoming items through the warehouse to maximize the probability a time-fenced group of future customer orders can be fulfilled from a set of closely located bins (efficient pick list). Demand intelligence described by time-fenced item correlations of incoming orders is a key data input. The problem is dynamic in that both the inventory state and pending order list are temporal.

## Sunday, 10:00AM - 10:50AM

### ■ Plenary

West Bldg 301AB

### Plenary: Riding Technology Waves: Perspectives and Opportunities for Operations Research

Plenary Session

Chair: Young-Jun Son, University of Arizona, Systems and Industrial Engineering, Engineering Building #20 Room 111, Tucson, AZ, 85721-0020, United States

#### 1 - Riding Technology Waves: Perspectives and Opportunities for Operations Research

Brenda Dietrich, Cornell University, Ithaca, NY, United States

This talk begins with a fly-by of almost six decades of information technology beginning with its use to automate business processes and extending to its current role in consumer self-service, the internet of things, and in intermediating social processes. The resulting "data exhaust" together with the availability of low cost computing capacity spawned the age of analytics, the rise of big data, the birth of cognitive computing and the reinvigoration of artificial intelligence. The past, current and potential role of analytic methods in these technology waves will be discussed, with focus on the opportunity to use analytics and automation to create new data. Areas in need of further study by the Operations Research community will be highlighted.

## Sunday, 11:00AM - 12:30PM

### ■ SB01

North Bldg 121A

### Methods for Multi-Stage Stochastic Optimization

Sponsored: Optimization/Optimization Under Uncertainty

Sponsored Session

Chair: Selvaprabu Nadarajah, College of Business, University of Illinois at Chicago, Chicago, IL, 60607, United States

#### 1 - Basis Function Selection in Approximate Linear Programming

Parshan Pakiman, University of Illinois at Chicago, Chicago, IL, United States, Selvaprabu Nadarajah, Negar Soheili, Qihan Lin

Approximate linear programs (ALPs) compute a value function approximation (VFA) for Markov decision processes (MDPs) using a linear combination of basis functions. The resulting VFA provides policies and lower and upper bounds on the optimal policy value. Basis functions - typically chosen in a problem-specific manner - affect the quality of these bounds. Constructing VFAs is thus challenging to a non-expert and may not guarantee tight bounds. To ease the use of ALPs, we develop a version using basis functions sampled from a parametric function class, which asymptotically leads to a near-optimal VFA. We establish finite sample guarantees and discuss numerical results on challenging applications.

#### 2 - Computational Experience with Asynchronous Projective Hedging

David L. Woodruff, University of California-Davis, Graduate School of Management, One Shields Avenue, Davis, CA, 95616, United States, Jean-Paul Watson, Jonathan Eckstein

Recent work by Eckstein and Combettes resulted in development of an algorithm for multi-stage, convex optimization problems with uncertain input data expressed as a set of scenarios. The algorithm is called Asynchronous Projective Hedging (APH). In this talk we describe computational experience with this algorithm primarily based on two well-known problems from the stochastic programming literature as well as experience with large mixed-integer problems. We explore various tradeoffs such as computational resources vs. wall-clock vs. solution quality as well as primal versus dual solution quality.

#### 3 - Solving Multi-period Mine Planning Models with Endogenous Uncertainty

Tito Homem-de-Mello, Universidad Adolfo Ibáñez, Santiago, Chile, Denis R. Saure, Tomas Lagos, Guido Lagos, Margaret Armstrong

We study a production scheduling problem in open pit mining under ore-grade uncertainty. We consider a multi-stage version of the problem, where there is a planning horizon of several time periods and where at each period the decision is: which blocks to extract and which to process, while satisfying extraction and processing capacity constraints. We propose an optimization with learning approach intended to tackle two of the main challenges presented by this problem: the scalability of the problem due to its large dimensions, and the robustness to uncertainty due to the inherent volatility of some of the parameters of the problem. We report computational experiments on a real-sized mine.

#### 4 - Revisiting Approximate Linear Programming Using a Saddle Point Approach

Selvaprabu Nadarajah, College of Business, University of Illinois at Chicago, 601 South Morgan Street., UH 2406, Chicago, IL, 60607, United States, Qihang Lin, Negar Soheili

Approximate linear programs (ALPs) are well-known models for approximating high dimensional Markov decision processes (MDPs). Solving ALPs exactly remains challenging, for instance, in applications where (i) the MDP includes nonlinear reward and transition dynamics and/or (ii) rich basis functions are required to obtain a good VFA. We address this tension between ALP theory and solvability by proposing a novel ALP saddle point reformulation and mirror descent solution approach that embeds iterative learning of constraint violation distributions. We present convergence guarantees for our approach and test it on inventory control and energy storage applications.

## ■ SB02

North Bldg 121B

### Joint Session OPT/Practice Curated: Optimization under Uncertainty in Energy and the Environment

Sponsored: Optimization/Optimization Under Uncertainty

Sponsored Session

Chair: Sarah G. Nurre, University of Arkansas, Walnut Creek, CA, 94596, United States

#### 1 - Resilient Transmission Hardening Planning in a High Renewable Penetration Era

Ali Bagheri, Oklahoma State University, Stillwater, OK, 74075, United States, Chaoyue Zhao, Feng Qiu, Jianhui Wang

Transmission system hardening is a practice to improve system resilience against possible disruptions. In a power system with a very high penetration of renewable energy, the system hardening will be further complicated by the uncertainty of renewable energy. We study the transmission line hardening planning problem in the context of probabilistic power flows injected by the high penetration of renewable energy. We assume that the information of renewable energy is incomplete. A data-driven two-stage stochastic model is formulated by considering the joint worst-case wind output distribution and transmission line contingencies.

#### 2 - An Integrated Two-level Inventory Problem: Applications to Battery Management in Electric Vehicle and Drone Swap Stations

Amin Asadi, University of Arkansas, 4207 Bell Engineering Center, 800 W. Dickson Street, Fayetteville, AR, 72701, United States, Sarah G. Nurre

We examine the new class of stochastic two-level integrated inventory problems (TOLIPs) with applications in drone and electric vehicle (EV) battery management. In the TOLIP, we model how first-level battery charge with battery charging, discharging, and replacement actions impact the deterioration and necessary actions for second-level battery capacity. In the context of a battery swap station, we formulate the TOLIP using a Markov Decision Process model with an uncertain demand for swaps. We perform computational experiments to derive optimal policies and deduce insights.

#### 3 - Stochastic Multi-Objective Water Allocation with Hedging Rule

Ming (Arthur) Yang, The Ohio State University, Columbus, OH, United States, Guzin Bayraksan

The problem of water shortage is usually caused by uneven distribution of rainfall, increasing water demand, or other environmental and human factors. In this study, we develop a mathematical model that applies hedging rules under inflow and demand uncertainties to provide an optimal strategy in managing and operating reservoirs. Hedging rules determine different rationing levels between users at certain trigger volumes of reservoirs during droughts. We develop time series models for the uncertain inflows and demands and model the problem as a multistage stochastic mixed integer program with multiple objectives. We present numerical results on a real-world multi-reservoir system.

#### 4 - Industrial Demand Response in Electricity Markets

Golbon Zakeri, University of Auckland, Dept of Eng Science, Private Bag 92019, Auckland, New Zealand

We will present a single stage optimization problem faced by a large industrial consumer of electricity who is capable responding to price, and also capable of offering interruptible load reserves. We will then extend our model to a multistage setting and report some computational results.

## ■ SB03

North Bldg 121C

### Entrepreneurship and Innovation

Sponsored: Technology, Innovation Management & Entrepreneurship

Sponsored Session

Chair: Sinan Erzurumlu, Babson College, Babson Park, MA, 02457, United States

#### 1 - Lean Startup Goal Conflict: Can Startups Manage Survival and Revenue Growth Simultaneously?

Emre Guzelsu, Boston University Questrom School of Business, 595 Commonwealth Ave, Boston, MA, 02215, United States, Nitin Joglekar, Moren Levesque

We examine if survival and revenue growth are separately or jointly determined at different stages of a business startup's life. By examining a startup from the Lean Startup perspective and incorporating dynamic capabilities, and in particular a micro strategy framework, we hypothesize that startups act differently in the early stages versus late stages of development. We test our hypothesis by applying a Hausman simultaneity test to data from the Kauffman Foundation Survey. We find that survival and revenue growth are separately determined in the early stages of a startup's life, but become more jointly determined in later stages.

#### 2 - Evaluating Telemedicine Adoption in Clinics: Accounting for Socioeconomic, Geographical, Organizational and Technological Antecedents

Xiaojin (Jim) Liu, University of Virginia, Darden, 100 Darden Boulevard, Charlottesville, VA, 22903, United States, Susan Goldstein, Kingshuk K. Sinha

This study involves a theoretically grounded empirical analysis on how socioeconomic, geographical, organizational and technological antecedents impact the adoption and use of telemedicine in health care delivery.

#### 3 - Shortages of Resources, Routines, Reputation or Regulations: Can Data and Analytics-driven Capabilities Assist Technology Entrepreneurs' Decisions?

Nitin Joglekar, Boston University Questrom School of Business, 595 Commonwealth Ave, Boston, MA, 02215, United States, Moren Levesque

We describe emerging studies that contribute to theory and create practical insights for managers in the technology arena, noting the dominance of either time or timing as crucial concepts in technology entrepreneurship. We also highlight the importance of information availability, which directs our attention to the timely availability and usage of data, along with computational technologies. We then argue that data-driven and analytics-driven capabilities can shape every aspect of the tradeoffs associated with the shortages of resources, routines, reputation or regulations and call for novel modes of decision-making for technology entrepreneurs.

#### 4 - Managing the Sources of Uncertainty in Entrepreneurial Decision Making: A Data Analysis Approach to Entrepreneurship and Innovation

Sinan Erzurumlu, Babson College, 231 Forest St, Tomasso 123, Babson Park, MA, 02457, United States

Abstract not available

## ■ SB04

North Bldg 122A

### Theory of Integer and Nonconvex Optimization

Sponsored: Optimization/Integer and Discrete Optimization

Sponsored Session

Chair: Eli Towle, University of Wisconsin-Madison, Madison, WI, 53705, United States

#### 1 - Mining Expression Trees to Improve Factorable Relaxations

Taotao He, Purdue University, 403 W. State St, West Lafayette, IN, 47906, United States, Mohit Tawarmalani

We introduce new relaxations for composite functions by convexifying the outer-function over a polytope, which models an ordering structure of outer-approximators of inner functions. We devise a fast combinatorial algorithm to separate the hypograph of concave-extendable supermodular outer-functions over the polytope. As a consequence, we obtain large classes of inequalities that tighten prevalent factorable programming. Moreover, these inequalities can be seamlessly embedded into a discretization scheme to approximate nonlinear programs with MIP. Combined with linearization, our techniques provide a framework for deriving cutting planes used in relaxation hierarchies and more.



## 2 - On the Complexity of Testing Attainment of the Optimal Value in Nonlinear Optimization

Jeffrey Zhang, Princeton University, 206 Lakeside Road, Princeton, NJ, 08540, United States, Amir Ali Ahmadi

We prove that it is strongly NP-Hard to test whether the optimal value of a nonlinear optimization problem is attained for certain degrees of the objective and constraints. Our results along with previously-known “Frank-Wolfe type” theorems settle the complexity for any combination of degrees. We also show that testing for some well-known sufficient conditions for attainment of the optimal value, such as coercivity of the objective function, compactness of the feasible set, and the Archimedean property of a related quadratic module is strongly NP-hard. Finally, we give SDP-based sufficient conditions for attainment of the optimal value, such as a new characterization of coercive polynomials.

## 3 - Exact Lexicographic Scheduling and Approximate Rescheduling

Dimitrios Letsios, Imperial College London, London, United Kingdom, Ruth Misener

We consider the fundamental two-stage robust makespan scheduling problem with a planning and a recovery phase. We show that planning using lexicographic optimization imposes optimal substructure that enables more efficient recovery with performance guarantees. We propose a novel lexicographic branch-and-bound method using vectorial bounds to deal with the lack of strong lower bounding techniques in exact lexicographic optimization MILP methods. Numerical analysis using standard commercial approaches substantiates the strength of our methods.

## 4 - Intersection Disjunctions for Reverse Convex Sets

Eli Towle, University of Wisconsin-Madison, Madison, WI, 53705, United States, James Luedtke

We present a framework to obtain valid inequalities for a reverse convex set, defined as the set of points in a polyhedron that lie outside a given open convex set. Our contribution is a disjunctive framework that uses basic solutions that lie outside the convex set to generate valid inequalities. We define a two-term disjunction for a reverse convex set. Next, we generalize this analysis to a multi-term disjunction by considering the convex set's recession directions. We present a polyhedral relaxation for each disjunctive term, allowing the approach to be used to generate disjunctive cuts.

## SB05

North Bldg 122B

### Semidefinite Optimization I

Sponsored: Optimization/Linear and Conic Optimization

Sponsored Session

Chair: Gary Au, PhD, University of Saskatchewan, SK, Canada

## 1 - Lift-and-project Lower Bounds for Hypermatching Relaxations

Yu Hin (Gary) Au, University of Saskatchewan, 106 Wiggins Road, 239 McLean Hall, Saskatoon, SK, S7N 5E6, Canada, Levent Tuncel, Nathan Lindzey

In 1999, Stephen and Tuncel showed that the Lovasz-Schrijver lift-and-project operator with semidefiniteness requires exponential effort to compute the integer hull of the standard linear relaxation of the matching polytope. Herein, we extend their results to b-matching polytope of complete uniform hypergraphs, utilizing some known results in association schemes.

## 2 - Using Mixed Precision Arithmetic in an Interior Point Method for SDP

Brian Borchers, New Mexico Institute of Mining & Technology, Dept of Mathematics Weir Hall, 801 LeRoy Place, Socorro, NM, 87801-4796, United States

Interior point methods for semidefinite programming are typically implemented in double precision floating point due to the fact that the Schur complement matrix that must be factored in each iteration becomes ill-conditioned as the iterates approach an optimal solution. Since single precision arithmetic is typically twice as fast as double precision, there are potential performance advantages to using single precision arithmetic in those parts of the algorithm and during those phases of the algorithm where single precision is sufficient. We describe an implementation of a mixed-precision primal-dual method for SDP and demonstrate its performance on benchmark problems.

## 3 - Two Dimensional Search Interior Point Algorithms for Linear Programming

Fabio T. Vitor, Kansas State University, 2061 Rathbone Hall, 1701B Platt St., Manhattan, KS, 66506, United States, Todd W. Easton

Interior point methods optimally solve linear programs by moving between feasible interior solutions. The majority of these algorithms move between solutions following a single direction. This talk presents novel primal and dual two dimensional interior point methods derived from affine and logarithmic barrier directions. These techniques use two potential improving directions to create a two dimensional problem. The optimal solution to this problem enables the algorithms to move to a new and improved feasible interior solution. Computational experiments show an improvement in solution time and iterations of approximately 12% when compared to the traditional one dimensional version.

## SB06

North Bldg 122C

### Computational Optimization

Sponsored: Optimization/Computational Optimization and Software

Sponsored Session

Chair: Julio Cesar Goetz, NHH, Department of Business and Management Science, Bergen, 5036, Norway

## 1 - A Novel Initialization Procedure for the Simplex Algorithm

Nikolaos Ploskas, Carnegie Mellon University, 5000 Forbes Avenue, Doherty Hall 3110, Pittsburgh, PA, 15213, United States, Nikolaos Sahinidis, Nikolaos Samaras

This paper addresses the computation of a starting basis for the simplex algorithm. We propose six algorithms for constructing an initial basis. We give the initial bases as input to the CPLEX solver and compare the performance of the primal and dual simplex algorithm using the proposed algorithms against CPLEX advanced starting basis and crash procedures. The best algorithm results in 7% and 6% average reduction of the execution time of CPLEX's primal and dual simplex algorithm, respectively. Taking into account only the hard instances, the proposed algorithm results in 23% and 32% average reduction of the execution time of CPLEX's primal and dual simplex algorithm, respectively.

## 2 - Warm-start of Interior Point Methods for Second Order Cone Optimization via Jordan Frames

Tamás Terlaky, Endowed Chair Professor, Lehigh University, 200 West Packer Avenue, Bethlehem, PA, 18015, United States, Imre Polik, Sertalp Bilal Cay

IPMs are the most popular approaches to solve Second Order Cone Optimization (SOCO) problems. We present a warm-start method for primal-dual IPMs to reduce the number of IPM steps needed to solve SOCO problems that appear in a Branch and Conic Cut (BCC) tree when solving Mixed Integer Second Order Cone Optimization (MISOCO) problems. Our method exploits the optimal Jordan frame of a related subproblem and provides a conic feasible primal-dual initial point for the self-dual embedding model by solving two auxiliary linear optimization problems. Numerical results on test problems in the CBLIB library show on average around 61% reduction of the IPM iterations for a variety of MISOCO problems.

## 3 - The Tight-and-cheap Conic Relaxation for the AC Optimal Power Flow Problem

Miguel F. Anjos, Professor, NSERC-Hydro-Quebec-Schneider Electric Industrial Research Chair, Inria International Chair, P.O. Box 6079, Station Centre-Ville, Montreal, QC, H3C 3A7, Canada, Christian Bingane, Sebastien Le Digabel

The classical ACOPF problem is highly non-convex and generally hard to solve. Convex relaxations, in particular, semidefinite, second-order cone, and linear relaxations have recently attracted significant interest. The semidefinite relaxation is the strongest among them and is exact for many cases, but the computational efficiency for solving large-scale semidefinite optimization is limited. We propose a new conic relaxation which is derived by a combination of semidefinite optimization and the reformulation-linearization technique. The proposed relaxation is stronger than the second-order cone relaxation and nearly as tight as the semidefinite relaxation.

## 4 - Valid Conic Inequalities for Hyperboloids and Non-convex Quadratic Cones

Julio C. Góez, Miguel F. Anjos

We use the disjunctive conic cut (DCC) approach to show the existence of valid conic inequalities for hyperboloids and non-convex quadratic cones when the disjunction is defined by parallel hyperplanes. For some of the cases, we show that for each of the branches of those sets, which are convex, the intersections with the DCCs provides the convex hull of the intersection of the branches with a parallel linear disjunction. For other cases, we show that this technique provides a second order cone equivalent reformulation for some non convex sets.

**5 - Advances in the Maximum K-cut Problem**

Vilmar Rodrigues de Sousa, Polytechnique, Montreal, QC, Canada,  
Miguel F. Anjos, Sebastien Le Digabel

We consider the maximum k-cut problem that consists in partitioning the vertex set of a graph into k subsets such that the sum of the weights of edges joining vertices in different subsets is maximized. We present our recent computational advances using associated semidefinite and linear programming relaxations.

**SB07**

North Bldg 123

**Joint Session OPT/Practice Curated: Transportation Network Analysis**

Sponsored: Optimization/Network Optimization

Sponsored Session

Chair: Ilke Bakir, Georgia Institute of Technology, Atlanta, GA, 30332, United States

Co-Chair: Bahar Cavdar, Middle East Technical University, Ankara, 06800, Turkey

**1 - Charm of Consistency - Two-stage Stochastic Team-orienteering Problem with Time Windows and Uncertain Services Requests**

Yongjia Song, Clemson University, 211 Fernow Street, 264  
Freeman Hall, Clemson, SC, 29634, United States,  
Marlin Wolf Ulmer, Barrett Thomas, Stein W. Wallace

We consider a practical problem in transportation, where service providers serve a set of regular customers over a long-term horizon, and also receive requests from additional on-demand customers on a daily basis. We formulate this problem as a two-stage stochastic team orienteering problem, which is challenging for two reasons. First, on the first stage assignment decisions need to be made under incomplete information. Second, decisions on the second stage require to solve a deterministic team-orienteering problem with time windows. We address the two challenges via a progressive hedging framework integrating a runtime efficient heuristic, adapted version of the multiple scenario approach.

**2 - An Integrated Fleet Management Model Introducing Alternative Fuel Trucks into Existing Diesel Fleets**

Ilke Bakir, University of Groningen, Groningen, Netherlands,,  
Alan Erera

We address the challenge of introducing alternative fuel trucks into an existing fleet, while making necessary structural changes and maintaining feasible operations. We develop an integrated fleet management model, which incorporates (i) opening new maintenance facilities, and (ii) fleet deployment, into a fleet replacement framework. We demonstrate that the integrated model makes use of information that is often overlooked by conventional fleet replacement strategies. We propose a Benders' decomposition framework and a Variable Neighborhood Search (VNS) algorithm for the integrated model; and demonstrate the performance of these methods with a comprehensive computational study.

**3 - Service Network Design with Mixed Autonomous Fleets**

Yannick Oskar Scherr, Technische Universität Braunschweig,  
Braunschweig, 38106, Germany, Bruno Albert Neumann-  
Saavedra, Mike Hewitt, Dirk C. Mattfeld

We introduce a service network design problem that integrates automated driving technologies into the tactical planning of parcel delivery. In this problem, autonomous vehicles at SAE level 4 are only permitted to drive in dedicated zones for the sake of traffic safety. Outside of these zones, manually operated vehicles must guide them in platoons, i.e., groups of vehicles following each other closely. Our integer linear program not only decides on vehicle routes and delivery operations but also on the number of autonomous and manually operated vehicles. Results show different solution structures depending on the fleet configuration and increased complexity due to platooning.

**4 - Sequential Optimization of the Intra-link Movement of an Emergency Response Vehicle Along Transportation Segments in the Connected Vehicle Environment**

Gaby Joe Hannoun, Virginia Tech, Blacksburg, VA, United States,  
Pamela Murray-Tuite, Kevin Heaslip, Thidapat Chantem

The ERVs face numerous safety hazards in their attempts to reach their destinations in a timely manner. An integer linear program (ILP) was previously developed to delineate the fastest intra-link ERV path and to determine the optimal assignment location of each downstream vehicle. Since the ILP is not scalable on large links, we present a dynamic approach to sequentially execute the ILP on short transportation segments. Recommendations are made about how to define the size of the transportation segments, based on factors related to downstream traffic conditions to achieve a near global optimal solution.

**SB08**

North Bldg 124A

**Paths and Clusters in Networks**

Sponsored: Optimization/Network Optimization

Sponsored Session

Chair: Foad Mahdavi Pajouh, University of Massachusetts, Boston, MA

**1 - Finding the Longest Path in a Structurally Perturbed Directed Acyclic Graph**

Golshan Madraki, Assistant Professor, Clarkson University,  
8 Clarkson Ave, Potsdam, NY, 13699, United States

In a structurally perturbed Directed Acyclic Graph (DAG) multiple edges are added and deleted simultaneously. Finding the longest path in the perturbed DAGs after perturbation without doing the calculation from the scratch is a critical challenge. The solution for this problem can solve and improve different problems in manufacturing system, transportation, telecommunications and etc. All previous researched considered single edge addition/deletion at a time. However, this research proposes an efficient algorithm called SPA to handle multiple edge deletions/additions with a single pass. This solution is more efficient in terms of time complexity than the previous approaches.

**2 - Exact IP-based Approaches for the Longest Induced Path Problem**

Dmytro Matsypura, University of Sydney, Sydney, Australia

Graph diameter, which is defined as the longest shortest path in the graph, is often used to quantify graph communication properties. In particular, it provides a very intuitive measure of the worst-case pairwise distance. However, in many practical settings where vertices can either fail or be overloaded, or destroyed by an adversary and thus, cannot be used in any communication or transportation path, it is natural to consider a more general measure of worst-case distance. One such measure is the longest induced path. The longest induced path problem is defined as the problem of finding a subgraph of largest cardinality such that this subgraph is a simple path. In contrast to the polynomially computable graph diameter, this problem is NP-hard. In this paper, we focus on exact solution approaches for the problem based on integer programming (IP) techniques. We first propose three conceptually different IP models and study their basic properties. To improve the performance of standard IP solvers, we propose an exact iterative algorithm, which solves a sequence of smaller IPs in order to obtain an optimal solution for the original problem. In addition, we develop a heuristic capable of finding induced paths in larger networks. Finally, we conduct an extensive computational study to evaluate the performance of the proposed solution methods.

**3 - Facility Location in Sparse Networks with Application to Aircraft Gate Assignment**

Mohammad Javad Naderi, Oklahoma State University,  
Stillwater, OK, 74075, United States, Austin Buchanan

Airport gate assignment problem is a problem that involves assigning scheduled flights to airport gates during a specific time period. Due to the fact that air traffic has almost doubled during the past three decades, there is a need for assigning flights to gates in an efficient way. Existing mathematical formulation approaches are developed mostly based on either the Quadratic Assignment Problem (QAP) or they include quadratic terms which both approaches can only be used to solve small scale problems. In this research, a novel graph based formulation is developed to exploit the sparsity of such networks. The efficiency of the formulation is examined by running the model for some numerical example.

**4 - Identifying Resilient Clusters in Networks with Randomly Changing Topology**

Maciej Rysz, University of Florida, 1751 Thomas St, Niceville, FL,  
32578, United States

We propose a two-stage stochastic programming framework for designing or identifying "resilient", or "repairable clusters in graphs whose topology may undergo a stochastic transformation. The reparability of a cluster is defined in terms of a budget constraint, which limits the repairs that can be made to the cluster when restoring its original structural properties after observing random changes to the graph's topology. A combinatorial branch-and-bound algorithm is developed, and its effectiveness is illustrated on the example of a two-stage stochastic maximum k-club problem.

**5 - The Most Degree-central Clique Problem**

Haonan Zhong, University of Massachusetts, Boston, MA,  
United States, Foad Mahdavi Pajouh

The most degree-central clique problem is to find a clique of maximum degree centrality in a graph. We addressed the computational complexity of this problem and proposed a series of theoretical foundations to build a combinatorial branch and bound algorithm for its solution. The performance of our proposed algorithm is tested on real life networks and random graphs.

## ■ SB09

North Bldg 124B

**First Order Methods for Saddle Point Problems**

Sponsored: Optimization/Nonlinear Programming

Sponsored Session

Chair: Necdet Serhat Aybat, University Park, PA, 16802, United States

**1 - Primal-dual Stochastic Gradient Method**

Yangyang Xu, Rensselaer Polytechnic Institute, Department of Mathematical Sciences, 110 8th Street, Troy, NY, 12118, United States

Stochastic gradient (SG) method has been used for problems with objective that is stochastic or an average of many functions. Most works on SG assume that the problem is unconstrained or has an easy-to-project constraint set. In this talk, I consider problems with a stochastic objective and also many functional constraints. For these problems, we propose a novel SG method based on augmented Lagrangian function. Each update, it inquires a stochastic subgradient of the objective, a subgradient and function value of one sampled constraint function, and function value of another sampled constraint function. Its convergence rate is shown. Numerical test on QCQP is conducted to show its efficiency.

**2 - Accelerated Stochastic Algorithms for Nonconvex Finite-sum and Multi-block Optimization**

Yu Yang, ISyE Ga Tech, Atlanta, GA, 30332, United States, Guanghui Lan

We first introduce a randomized accelerated proximal gradient (RapGrad) method for solving a class of nonconvex optimization problems consisting of the sum of  $m$  component functions, and show that it can significantly reduce the number of gradient computations especially when the condition number, i.e., the ratio between the Lipschitz constant and negative curvature, is large. Inspired by RapGrad, we also develop a new randomized accelerated proximal dual (RapDual) method for solving a class of multi-block nonconvex optimization problems coupled with linear constraints. We demonstrate that RapDual can also save up to a factor of  $O(\sqrt{m})$  projection subproblems than its deterministic counterpart, where  $m$  denotes the number of blocks.

**3 - Primal-dual Methods for General Convex-concave Saddle Point Problems**

Erfan Yazdandoost Hamedani, Pennsylvania State University, State College, PA, 16801, United States, Necdet Serhat Aybat

In this research we propose a primal-dual algorithm with a momentum term that can be viewed as a generalization of the method proposed by Chambolle and Pock in 2016 to solve saddle point problems defined by a convex-concave function  $L(x,y)=f(x)+F(x,y)-h(y)$  with a general coupling term  $F(x,y)$  that is not assumed to be bilinear. We derive error bounds in terms of Lagrangian function for the ergodic sequence of iterates; in particular, we show  $O(1/k)$  rate when the problem is merely convex. Furthermore, assuming  $F(x,\cdot)$  is linear in  $y$  for each fixed  $x$  and  $f$  is strongly convex, we can obtain the ergodic convergence rate of  $O(1/k^2)$ .

**4 - Complexity of a Quadratic Penalty Accelerated Inexact Proximal Point Method for Solving Linearly Constrained Nonconvex Composite Programs**

Renato Monteiro, School of ISyE, Georgia Tech, Atlanta, GA, 30332, United States

This talk discusses the complexity of a quadratic penalty accelerated inexact proximal point method for solving a linearly constrained nonconvex composite program. Its objective function is of the form  $f+h$  where  $f$  is a differentiable function whose gradient is Lipschitz continuous and  $h$  is a closed convex function with bounded domain. The method consists of applying an accelerated inexact proximal point method to solve a sequence of quadratic penalized subproblems associated to the linearly constrained problem. Each subproblem is then approximately solved by an accelerated composite gradient method. Numerical results showing the efficiency of the proposed method are given.

## ■ SB10

North Bldg 125A

**MSOM Distinguished Fellow Talk**

Sponsored: Manufacturing &amp; Service Oper Mgmt

Sponsored Session

Chair: Gad Allon, University of Pennsylvania, 3730 Walnut Street, Philadelphia, PA, 19104, United States

**1 - Selected Adventures in Policy Modeling**

Edward H. Kaplan, Yale University, Yale School of Management, Box 208200, New Haven, CT, 06520-8200, United States

Policy Modeling refers to the application of operations research, statistics, and other quantitative methods to model policy problems. Recognizing that analyses of all sorts often exhibit diminishing returns in insight to effort, the hope is to

capture key features of various policy issues with relatively simple “first-strike” models. Problem selection and formulation thus compete with the mathematics of solution methods in determining successful applications. I will review some personal adventures in policy modeling selected from public housing, HIV/AIDS prevention, bioterror preparedness, counterterrorism, and immigration policy.

## ■ SB11

North Bldg 125B

**Operational Issues in Agriculture**

Sponsored: Manufacturing &amp; Service Oper Mgmt/IFORM

Sponsored Session

Chair: Buket Avci, Singapore Management University, 50 Stamford Road, Singapore, 178899, Singapore

**1 - Optimal Procurement from Multiple Contracts in Agricultural Processing: Implications for Biomass Commercialization**

Buket Avci, Singapore Management University, 50 Stamford Road, Singapore, 178899, Singapore, Onur Boyabatli, Bin Li

We study the optimal procurement strategy of an agricultural processor that procures a commodity input from multiple contracts to produce a commodity output in the presence of input and output spot price uncertainties. We investigate the impact of spot price correlation on the procurement strategy and profitability. We also examine the impact of commercializing output waste as biomass on the profitability and greenhouse gas emissions. Calibrating our model with data from palm industry, we show that failing to update procurement strategy after commercialization leads to a significant profit loss and commercialization of biomass can increase emissions due to change in the procurement strategy.

**2 - Integrated Optimization of Fertilizer Procurement, Cultivation, and Harvesting**

Yangfang (Helen) Zhou, Assistant Professor, Singapore Management University, Singapore, 178899, Singapore, Onur Boyabatli, Lusheng Shao

We consider the integrated optimization of three key operational decisions in farm planning: fertilizer procurement via both contract and spot markets; cultivation and harvesting with limited respective resources in the presence of uncertain farm yield and labor cost. We model this problem as a three-stage stochastic program and characterize the optimal decisions in each stage. Using a numerical study calibrated to real data, we characterize the value of the integrated optimization and examine how the uncertainties in the farm yield and labor cost affect the farm profitability, cultivation decisions, and two measures of food loss: un-harvested yield and the yield gap.

**3 - Food Safety Control in the Developing Economies. Centralization Versus Decentralization**

Duo Shi, The Chinese University of Hong Kong, Shenzhen, Shenzhen, China, Lingxiu Dong, Iva Petrova Rashkova

We analytically investigate how the food safety outcome is affected by the structure of government auditing agencies in the developing economies. We find that a decentralized control structure may beat a centralized control structure, and higher auditing capabilities from the agencies may lead to a worse food safety outcome. We also propose a responsibility reallocation approach to further improve the current decentralized structure.

## ■ SB12

North Bldg 126A

**Joint Session OR Frontiers/Integer Programming/ICS: Machine Learning and Discrete Optimization I**

Emerging Topic: OR Frontiers

Emerging Topic Session

Chair: Bistra Dilkina, University of Southern California, Los Angeles, CA, 90089, United States

**1 - Deep Learning for MIP Branch and Bound**

Bistra Dilkina, University of Southern California, 941 Bloom Walk, Los Angeles, CA, 90089, United States, Aaron Ferber, Elias B. Khalil

Effective branching decisions are one of the key components to designing more scalable MIP branch and bound algorithms. We leverage a deep learning approach to obtain a predictive model that works well over distributions of similar instances. The features used as input to the model are generic so that transfer to new instances is seamless. Experimental results are encouraging.



## 2 - Recent Advances in Algorithm Configuration and Algorithm Tuning

Meinolf Sellmann, General Electric, 82 Diamond Avenue,  
Cortlandt Manor, NY, 10567, United States

We present new results on highly efficient parallel algorithm configuration as well as algorithm portfolios. Our deterministic parallelization of the GGA tuner is shown to achieve near-linear speed-ups up to 96 cores. Moreover, we show that a self-configured CSHC portfolio builder with a new recourse mechanism sets a new state of the art in solver selection.

## 3 - Learning to Search via Retrospective Imitation

Jialin Song, California Institute of Technology, 1200 E. California  
Blvd, MC 305-16, Pasadena, CA, 91125, United States, Ravi Lanka,  
Albert Zhao, Yisong Yue, Masahiro Ono

We study the general problem of learning a good search policy. To do so, we propose the retrospective imitation setting, which builds upon imitation learning in two ways. First, retrospective imitation uses feedback provided by retrospective analysis of search traces. Second, the policy can learn from its own decisions and mistakes without requiring repeated feedback from an external expert. Combined, these two properties allow our approach to iteratively scale up to larger problem sizes than the initial problem size for which expert demonstrations were provided. We showcase the effectiveness of our approach on learning node selection and pruning policies in branch-and-bound.

## 4 - Learning-Theoretic Foundations of Algorithm Configuration for Combinatorial Partitioning Problems

Ellen Vitercik, Carnegie Mellon University, 5000 Forbes Ave,  
Pittsburgh, PA, 15213, United States, Maria-Florina Balcan,  
Vaishnavh Nagarajan, Colin White

Data-driven algorithm design, that is, choosing the best algorithm for a specific application, is a crucial problem in modern data science. Practitioners often optimize over parameterized algorithm families, tuning parameters based on problems from their domain. While effective in practice, these procedures generally have not come with provable guarantees. I will present work that helps put data-driven combinatorial algorithm configuration on firm foundations. We provide strong computational and statistical performance guarantees for several important problems, including clustering algorithm configuration and integer quadratic programming approximation algorithm configuration.

## 5 - Learning to Branch

Tuomas W. Sandholm, Angel Jordan Professor of Computer  
Science, Carnegie Mellon University, Gates Center for Computer  
Science, Pittsburgh, PA, 15213, United States, Maria Florina  
Balcan, Travis Dick, Ellen Vitercik

Tree search algorithms, e.g. branch-and-bound, are the most widely used tools for combinatorial and nonconvex problems (e.g., MIP and CSP). To keep the tree small, it is crucial to decide, when expanding a node, which question (e.g., variable) to branch on to partition the remaining space. Many techniques have been proposed, but theory was lacking. We show how to use machine learning to determine an optimal weighting of any set of partitioning procedures for the instance distribution at hand using samples from the distribution. We provide the first sample complexity guarantees for tree search algorithm configuration. The theory gives rise to a learning algorithm which dramatically reduces tree size.

## SB13

North Bldg 126B

### Nonprofit and For-profit Operations in Healthcare

Sponsored: Manufacturing & Service Oper Mgmt/Healthcare  
Operations

Sponsored Session

Chair: Lauren Xiaoyuan Lu, University of North Carolina at Chapel Hill  
- Kenan Flagler, Chapel Hill, NC, 27599, United States

## 1 - Does Ownership Conversion from Nonprofit to For-profit Benefit the Public? Evidence from U.S. Nursing Homes

Lauren Xiaoyuan Lu, University of North Carolina at Chapel Hill -  
Kenan Flagler, Kenan-Flagler Business School, CB #3490, Mccoll  
Building 4701, Chapel Hill, NC, 27599, United States, Susan F. Lu

In the last few decades, many healthcare institutions converted their ownership from nonprofit to for-profit, contributing to an increased presence of for-profit ownership in the U.S. healthcare sector. There have been contradicting views on whether such ownership conversions benefit the public. Employing a large panel dataset of U.S. nursing homes dated from 2006 to 2015, we conduct a difference-in-differences analysis on converting facilities' financial performance, operating policies, and service quality.

## 2 - Perishable Inventory Sharing in a Two-location System

Can Zhang, Duke University, Durham, NC, United States,  
Turgay Ayer, Chelsea C. White

Motivated by a platelet inventory management problem in a local hospital network, we study an inventory sharing problem for perishable products in a two-location system. We derive structural properties of the optimal policy and present managerial insights that are significantly different from those in existing studies for traditional non-perishable products.

## 3 - Operational Drivers of Stock-outs in Reproductive Health Supply Chains: An Empirical Study

Amir Karimi, University of Minnesota, Minneapolis, MN, 55408,  
United States, Karthik Natarajan, Kingshuk K. Sinha

Despite the widespread prevalence of contraceptive stock-outs in practice, very little is known about the drivers of stock-outs and this forms the motivating context for our study. Utilizing field data collected in developing countries, we investigate how different factors such as a health facility's geographic location and product variety impact the likelihood of stock-outs. In addition, we explore the effect of two commonly used inventory management practices that have the potential to serve as mitigation mechanisms to reduce the risk of stock-outs. Our findings have important implications for resource allocation and supply management of health commodities in developing countries.

## 4 - Optimal Motorcycle Routing in Sample Transportation for Diagnostic Networks

Jonas Oddur Jonasson, MIT Sloan School of Management,  
30 Memorial Drive, E62-588, Cambridge, MA, 02142,  
United States, Sarang Deo, Emma L. Gibson, Mphatso Kachule,  
Kara Palamountain

Due to limited resources, diagnostic and disease monitoring services in sub-Saharan Africa are delivered through a network of clinics and laboratories. An ongoing challenge is to develop cost-effective sample transportation systems to ensure short turnaround times of results. Using data from Riders for Health in Malawi we develop an algorithm for the daily route optimization of couriers in a diagnostic network and evaluate its impact on turnaround times and distance driven. Our method maintains current service levels while requiring approximately 90,000 km less distance travelled per year.

## SB14

North Bldg 126C

### Stochastic Models in Service Operations

Sponsored: Manufacturing & Service Oper Mgmt/Service  
Operations

Sponsored Session

Chair: Baris Ata, University of Chicago, Chicago, IL, 60637,  
United States

Co-Chair: Xiaoshan Peng, Indiana University, Bloomington, IN, 47401,  
United States

## 1 - Process Flexibility for Multi Period Production Systems

Yuan Zhong, University of Chicago / Booth School of Business,  
5807 S. Woodlawn Avenue, Chicago, IL, 60637, United States,  
Cong Shi, Yehua Wei

We consider process flexibility in a multi-period make-to-order production (MTO) system. First, using a new chaining notion, termed the Generalized Chaining Gap (GCG), we prove that in a general system with high utilization, a sparse flexibility structure with  $m+n$  arcs is needed to achieve similar performance as full flexibility, where  $m$  and  $n$  are the number of plants and of products, respectively. We also provide a simple and efficient algorithm for finding such sparse structures. Moreover, we show that the requirement of  $m+n$  arcs is necessary, as for some systems, even the best flexibility structure with  $m+n-1$  arcs cannot achieve the same asymptotic performance as full flexibility.

## 2 - On the Control of Polling System with Large Switchover Times

Yue Hu, Columbia University, c/o Clara Magram, 4th Floor West,  
New York, NY, 10027, United States, Jing Dong, Ohad Perry

We study the control problem of polling systems with large switchover times. Under the proper scaling and cyclic controls, we show that the exhaustive switching policy is asymptotically optimal in minimizing the long-run average holding cost among all switching policies that achieve certain long-run regularity. To establish the asymptotic optimality, we characterize the fluid scaling limit of the system as a hybrid dynamical system and prove the corresponding interchange-of-limit results. We also study properties of several classes of controls of interests.

**3 - Managing the Callback Option under Arrival Rate Uncertainty**

Xiaoshan Peng, Indiana University, Kelley School, Bloomington, IN, United States, Baris Ata

We study how to manage the callback option effectively to mitigate congestion due to temporary surges in the arrivals to a call center. Initially, we allow complete foresight policies that look into the entire future. We consider the setting where some customers may reject the callback offer. We show that a modified lookahead policy that looks into the future arrivals and service completion times for the next p/h time units and uses the current number of customers in the system who previously rejected a callback offer is pathwise optimal. Building on the insights gleaned from the optimal lookahead policies, we also propose a non-anticipating policy, referred to as the line policy.

**4 - Using Hospital Admission Predictions at Triage for Improving Patient Flow**

Serhan Ziya, University of North Carolina, Department of Stat and OR, 356 Hanes Hall Cb#3260, Chapel Hill, NC, 27599, United States, Sukriye Nilay Argon, Wanyi Chen

We investigate how predictions for hospital admissions at the time of triage can be used to reduce boarding times and overall emergency department length-of-stay. Using simple mathematical models, we develop methods for making early bed reservations for patients at triage depending on the predictions for hospital admissions and also possibly on time-of-day and census levels. We then compare the performances of these methods using a simulation model constructed using data from an emergency department.

**SB15**

North Bldg 127A

**Innovative Business Models**

Sponsored: Manufacturing & Service Oper Mgmt/Service Operations

Sponsored Session

Chair: Kamalini Ramdas, London Business School, London, NW1 4SA, United Kingdom

**1 - Mobile Technology in Online Retail: Strengths and Limitations**

Jose A. Guajardo, University of California-Berkeley, Haas School of Business, 545 Student Services Bldg, Berkeley, CA, 94720-1900, United States

We empirically analyze central aspects of the role of mobile technology in the overall customer experience in online retailing.

**2 - Impact of After Sales Service on Technology Adoption in Emerging Markets**

Amrita Kundu, London Business School, Regent's Park, PhD Office - MSO, London, NW1 4SA, United Kingdom, Kamalini Ramdas

We aim to empirically assess the impact of after-sales interactions on adoption and continued use of new technology in emerging markets. In particular, we estimate the impact of after-sales service and customer engagement on new customer acquisition and customer retention for a solar distribution company operating in off-grid communities in East Africa. We combine a proprietary dataset obtained from a solar distribution company and secondary data sources to estimate the market impact of after-sales interactions.

**3 - When is the Root of All Evil Not Money? The Impact of Load on Operational Risk at a Commercial Bank**

Yuqian Xu, University of Illinois at Urbana-Champaign, Wohlers Hall 487, 1206 S. 6th St, Champaign, IL, 61820, United States, Fangyun Tan, Serguei Netessine

We use a unique operational risk event data set from a commercial bank in China that contains 1,441 operational risk events in two years. We find that workload has a U-shaped impact on operational risk frequency. In addition, we show that workload has an inverted-U shaped impact on bank profit. We compare our optimal staffing policy with bank's original policy, and estimate that the new staffing policy would reduce the current number of employees by 7.56%, which would further decrease the number of risk events by 4.51%, cut the total losses by 4.58%, and increase profits by 1.24%.

**SB16**

North Bldg 127B

**Sustainable Operations**

Sponsored: Manufacturing & Service Oper Mgmt/Sustainable Operations

Sponsored Session

Chair: Basak Kalkanci, Georgia Institute of Technology, Atlanta, GA, 30339, United States

**1 - Encouraging Energy Efficiency Investment in a Supply Chain: A Behavioral Investigation**

Jason Quang Nguyen, University of New South Wales, UNSW Business School, Sydney, 2052, Australia, Karen L. Donohue, Behrooz Pourghannad

Suppliers' propensity to accept external assistance from third-party organizations and buyers and undertake subsequent Energy Efficiency investments is still elusive. Through controlled behavioral experiments, this paper studies how the source of external assistance, contract framing and characteristics of the investment influence the supplier's propensity to undertake the assessments and subsequent investments.

**2 - Predicting Carbon Abatement Disclosures using Text Analysis**

Christian Blanco, Ohio State University, 640 Fisher Hall, 2100 Neil Ave Columbus, Columbus, OH, 43201, United States

Firms may choose not to disclose financial information on carbon abatement opportunities for various reasons. One reason for this is that firms are strategic about what they may disclose. Another reason is that firms may not yet be aware of the precise outcome of these opportunities. We explore conditions when firms may or may not disclose financial information on carbon abatement opportunities. We will explore this question using over 40,000 carbon abatement opportunities reported to CDP from 2011-2016.

**3 - The Impact of Input- vs. Output-based Farm Subsidies on Farmer Welfare and Income Inequality**

Yulan Wang, Hong Kong Polytechnic University, Department of Logistics and Maritime Studies, Faculty of Business, Kowloon, Hong Kong, Christopher S. Tang, Ming Zhao

We examine the implications of two commonly observed farm subsidy schemes in this paper. The first scheme is input-based while the second is output-based. By analyzing a stylized model that captures the yield heterogeneity across farmers who engage in quantity competition, we find that both schemes can improve farmers' income. However, the input-based subsidy scheme narrows the income gap between farmers, but the output-based scheme widens this gap. The output-based subsidy scheme outperforms the input-based subsidy scheme in terms of total farmer income and farmer productivity. We find these results continued to hold when the farmer's yield rate is uncertain.

**4 - How Does Regulation Stimulate the Good and the Bad Innovations?**

Keija Hu, Owen School of Business, Vanderbilt University, Nashville, TN, United States, Mark Cohen

Using data to quantify the technology progress in the auto industry in the past 20 years, we analyze how regulation stimulates both the good and bad innovations.

**SB17**

North Bldg 127C

**Data-Driven Supply Chain Operations**

Sponsored: Manufacturing & Service Oper Mgmt/Supply Chain

Sponsored Session

Chair: Max Shen, JD.com, Santa Clara, CA, 95054, United States

Co-Chair: Sheng Liu, University of California, Berkeley, Berkeley, CA, 94709, United States

**1 - Bayesian Inventory Management: Demand Learning via Exploration Boosts**

Michael Kim, PhD, Sauder School of Business, University of British Columbia, Vancouver, BC, Canada

We investigate inventory management problems where parameters of the demand distribution are not known a priori, but need to be learned using right-censored sales data. The goal of this paper is to characterize the structure of the optimal inventory policy to better understand the basic mechanism by which learning and inventory control are optimally combined. To this end, through an analysis of the Bayesian dynamic programming (BDP) equations, our main result shows that BDP-optimal decisions can be expressed as the sum of a myopic-optimal decision plus an "exploration boost" that is proportional to the posterior variance-to-mean ratio of the demand.

## 2 - Dynamic Procurement of New Products with Covariate Information- The Residual Tree Method

Gah-Yi Ban, London Business School, Regent's Park, London, NW1 4SA, United Kingdom, Jeremie Gallien, Adam J. Mersereau

We study the practice-motivated problem of dynamically procuring a new, short life-cycle product under demand uncertainty. The firm does not know the demand for the new product but has data on similar products sold in the past, including demand histories and covariate information such as product characteristics. We propose a new, combined forecasting and optimization algorithm called the Residual Tree method, and analyze its performance via epidemiological convergence theory and computations using data from Zara. Our method generalizes the classical Scenario Tree method by using covariates to link historical data on similar products to construct demand forecasts for the new product.

## 3 - Designing Response Supply Chain Against Bioattacks

Yun Zhang, MIT, Cambridge, MA, United States, Nikolaos Trichakis, David Simchi-Levi

This work studies the problem of prepositioning medical inventory against bioattacks. We model it as a general two-stage inventory optimization problem on a network, and provide tractable and optimal solution methods. We collect data from publicly available sources and perform a thorough case study against anthrax attacks.

## 4 - Data-driven Order Assignment for Last Mile Delivery

Sheng Liu, University of California, Berkeley, 1731 Spruce St Unit B, Berkeley, CA, 94709, United States, Long He, Zuo-Jun Max Shen

Motivated by a food delivery service provider, we discuss a data-driven framework to model the delivery performance and optimize the order assignment decision using real delivery data. Leveraging on classical results in routing literature and machine learning approaches, we propose a prediction model for the delivery tour distance. We then propose a sample average approximation model and a distributionally robust model for order assignment. A branch-and-price algorithm is developed to solve both models efficiently. In the numerical study, we show the benefits of data-driven order assignment models integrated with delivery tour prediction, compared to classical vehicle routing models.

## ■ SB18

North Bldg 128A

## New Topics in Supply Chain Management

Sponsored: Manufacturing & Service Oper Mgmt/Supply Chain  
Sponsored Session

Chair: Serguei Netessine, The Wharton School, Philadelphia, PA, 19104, United States

## 1 - Supply Chain and Antitrust Governance: Supply Chain and Antitrust Governance: Can Contractual Agreements Reinforce the "Illinois Brick"?

Nitish Jain, London Business School, Sussex Place, Regent's Park, London, NW1 4SA, United Kingdom, Sameer Hasija, Serguei Netessine, Serguei Netessine

In 1977, the U.S. Supreme Court issued a key ruling in *Illinois Brick Co v Illinois* case that debarred indirect purchasers to sue for recovery of antitrust damages. This ruling, however, can be exploited by firms to form collusion; muting the effectiveness of private enforcers in fighting antitrust violations. In this paper, using a supply chain lens, we characterize the conditions that facilitate or deter collusion formation. Our findings provide actionable insights to public enforcers in active case selection and investigation of antitrust violations.

## 2 - Do Flexibility and Chaining Really Help? An Empirical Analysis of Automotive Plant Networks

Vivek Choudhary, INSEAD Business School, 1 Ayer Rajah Avenue, Singapore, Singapore, Sameer Hasija, Serguei Netessine

We study production networks of automotive assembly plants to shed new light on the impact of flexibility on performance. We reconcile the extant empirical and modeling literature by testing existing flexibility indices. We introduce new flexibility indices to assess the relationship between flexibility and productivity to explain the trend of real-life networks. We empirically show that intermediate levels of flexibility are optimal due to trade-off between better flexibility and productivity, however, chaining may not be the optimal configuration if changeover losses of flexible plants are accounted for.

## 3 - Worker Poaching in a Supply Chain: Enemy from Within?

Gad Allon, University of Pennsylvania, 3730 Walnut Street, Philadelphia, PA, 19104, United States, Evan Barlow, Achal Bassamboo

Poaching workers has become a universal practice. We explore worker poaching between firms linked in a supply chain. We show that the classical intuition from labor economics is insufficient in explaining poaching between supply chain partners. We also show how and under what conditions worker poaching can

actually improve supply chain performance. Finally, we show how the equilibrium identity of the supply chain bottleneck depends on the interaction between hiring, poaching, and productivity.

## 4 - Sustaining Forests and Smallholders by Eliminating Payment Delay in a Commodity Supply Chain

Dan Andrei Iancu, Associate Professor, Stanford University, 655 Knight Way, Stanford, CA, 94107, United States, Joann de Zegher, Erica Plambeck

Motivated by the Indonesian palm oil industry, we propose a profitable way in which large buyers can simultaneously improve farmer livelihoods and halt illegal deforestation in their supply chains. Currently, farmers are paid with delays, and buyers avoid sourcing from illegally-deforested land by monitoring individual farmers. Instead, we propose rewarding all farmers in a village by eliminating payment delay if no production occurs on illegally-deforested land in the village. Using field data, dynamic programming and game theory, we show how this village-level incentive improves productivity and profitability for farmers, processors and buyers, and best halts illegal deforestation.

## ■ SB19

North Bldg 128B

## Digital Ad Auctions

Sponsored: Revenue Management & Pricing  
Sponsored Session

Chair: Hemant K. Bhargava, University of California, Davis, CA, 95616, United States

Co-Chair: Ramnik Arora, Facebook, Menlo Park, CA, 9, United States

## 1 - No Really, What Does Any of this Mean?: Proxy Metrics in Ad Auctions

Dan Chapsky, Facebook, New York, NY, United States

Digital ad auctions are rife with data available for interpretation by marketers. In general, some combination of data on clicks, views, conversions is used to interpret which strategies are actually delivering value. Much research has been done to show that the only true method of measuring value is through randomized control trials, but the majority of online ads go through no such experimentation. In this talk we will be discussing exploratory research on which non-experimental measurement methods work and when.

## 2 - Pacing Mechanisms for Ad Auctions

Nicolas Stier-Moses, Facebook, 1 Hacker Way, Menlo Park, CA, 94025, United States, Vincent Conitzer, Christian Kroer, Debmalaya Panigrahi, Okke Schrijvers, Eric Sodomka, Chris Wilkens

Online ad auction platforms typically rely on pacing mechanisms to ensure that campaign daily budgets are consistent with maximum bids. The goal is maximizing advertisers' utilities. We model this process and connect it to market equilibria. The goal of this system is being able to forecast market outcomes.

## 3 - Budget-constrained Ad Selection in Large-scale Advertising Systems

Hemant K. Bhargava, University of California, Gh-3108, Graduate School of Management, Davis, CA, 95616, United States, Ramnik Arora

Internet advertising systems operate at large scale with tens of thousands of potential ads mapping to an individual or a keyword. Moreover, search results need to be computed in a fraction of a second to provide seamless user experience. We report results of experiments with a hierarchical decomposition approach where candidate ads are sequentially pruned using a finer and more computationally expensive machine learning model and/or higher number of user / ad features.

## 4 - On Optimal Auctions for Mixing Exclusive and Shared Matching in Platforms

Hemant K. Bhargava, University of California, Gh-3108, Graduate School of Management, Davis, CA, 95616, United States, Gergely Csapo, Rudolf Muller

We study auctions that can produce either exclusive or shared allocations, and involve two dimensions of information, a bidder's valuations for exclusive and shared allocation, respectively. We formulate the revenue-maximizing incentive-compatible auction, and demonstrate that our proposed solution, a two-dimensional reserve-price based mechanism (RM), has excellent revenue performance.



## ■ SB20

North Bldg 129A

**Revenue Management for Marketplaces**

Sponsored: Revenue Management &amp; Pricing

Sponsored Session

Chair: Omar Besbes, Columbia University, New York, NY, 10027, United States

Co-Chair: Ilan Lobel, New York University, New York University, New York, NY, 10012, United States

**1 - Frustration-based Promotions: Field Experiments in Ride Sharing**

Maxime Cohen, NYU Stern, Baek Jung Kim, Michael-David Fiszer

In this talk, we examine whether a firm should proactively send compensation to users who have experienced a frustration (i.e., a poor service quality). In collaboration with one of the leading ride-sharing platforms, Via, we designed and ran three field experiments to investigate how different compensation types affect the engagement of riders who experienced a frustration.

**2 - Position Ranking and Auctions for Online Marketplaces**

Heng Zhang, USC Marshall School of Business, Bridge Memorial Hall - BRI 401B, 3670 Trousdale Parkway, Los Angeles, CA, 90089, United States, Leon Yang Chu, Hamid Nazerzadeh

We study how online e-commerce platforms should rank products displayed to consumers, and utilize the top slots. We present a model that considers consumers' search costs and the externalities sellers impose on each other, which allows us to study a multi-objective optimization, whose objective includes consumer, seller surplus, and the sales revenue, and derive the optimal ranking decision. In addition, we propose a surplus-ordered ranking mechanism, motivated in part by Amazon's sponsored search program, for selling top slots. We show that our mechanism is near-optimal, performing significantly better than those that do not incentivize the sellers to reveal their private information.

**3 - Surge Pricing and Its Spatial Supply Response**

Francisco Javier Castro, Columbia University, Columbia School of Business, 527 West 121st, New York, NY, 10027, United States, Omar Besbes, Ilan Lobel

We study the pricing problem faced by a platform matching price sensitive customers to flexible supply units in a city. The platform sets prices, and drivers react by choosing where to travel based on prices, travel costs and congestion levels. By uncovering an appropriate knapsack structure to the platform's problem, we first establish a characterization of the optimal solution and its supply response. We then tailor the analysis to a demand shock and derive in quasi-closed form the optimal solution. The platform uses prices to create damaged regions where demand is shut-down or driver congestion is artificially high, incentivizing some drivers to travel both toward the demand shock and away from it.

**4 - Value Loss in Allocation Systems with Provider Guarantees**

Xavier Warnes, Stanford University, Yonatan Gur, Dan Andrei Iancu

Centralized planning systems that allocate tasks to workers or service providers must often restrict their allocations so as to ensure particular (welfare) guarantees to their workers. Such restrictions can generate losses in the total value created or in the system's share of that value. Our work provides a uniform bound for these losses under a very broad class of restrictions due to worker guarantees. The bound only depends on the number and the heterogeneity of the service providers, and allows identifying the guarantees that are most stringent. We also show that such value losses remain small in practical settings of interest calibrated with real data.

## ■ SB21

North Bldg 129B

**Data Driven Revenue Management**

Sponsored: Revenue Management &amp; Pricing

Sponsored Session

Chair: Jake Feldman, Washington University in St. Louis

**1 - Pricing Discounts in Electric Vehicle Share Systems**

Bobby Nyotta, Fernanda Bravo, Jacob Feldman

We study the use of pricing discounts in an electric vehicle share system with free-floating parking. Specifically, we examine the optimal policy for the operator to offer free rides to the charging stations. Free rides can help to keep vehicles charged and to rebalance the system, however a revenue loss is experienced. Based on the optimal policy structure, we decompose and approximate the problem with an algorithm that performs well on real problem instances.

**2 - A Choice Modeling Framework for Service Time Windows**

Xiao Lei, Columbia University, 500 W. 120th St., New York, NY, 10027, United States, na, Adam Elmachroub

On-demand services have become increasingly common, and typically allow customers to choose a time window to receive the service. As a result, there is a natural trade-off between on-time customer service and operational cost. To address this issue, some service providers offer large time windows with rewards, together with the normal small ones. In this paper, we provide a choice modeling framework to address how customers choose among time windows, and apply this framework to evaluate various strategies for time window design.

**3 - When Behavioral Operations Meets Optimization: Evidence From a Large Field Experiment on Behavioral Bin-packing Algorithms**

Jiankun Sun, Northwestern University, Evanston, IL, United States, Dennis Zhang, Haoyuan Hu, Jan Van Mieghem

In logistics, optimization algorithms are widely deployed to augment and empower human. However, human may not execute the algorithm solutions for various reasons, which might cause efficiency loss and cost increase. We examine how a behavioral optimization algorithm affects human's compliance rate of algorithm solutions, working efficiency and estimate the corresponding economic value by running a field experiment on two bin-packing algorithms. The first algorithm is a conventional heuristic bin-packing algorithm, while the second algorithm extends the first one by considering human behavior in choosing the packing boxes.

**4 - Revenue Management versus Machine Learning:****Finding Optimal Product Displays at Alibaba**

Jacob Feldman, Olin Business School, 6 Portland Court, Saint Louis, MO, 63108-1291, United States, Dennis Zhang

We compare the performance of two state of the art approaches for finding the optimal set of products to display to customers arriving to Alibaba. The first procedure embeds hundreds of product and customer features within a sophisticated machine learning algorithm that is used to estimate the purchase probabilities of each product for the customer at hand. The products with largest expected revenue (revenue\*predicted purchase probability) are then made available for purchase. Our second approach uses a featurized MNL model to predict purchase probabilities for each arriving customer and then solves cardinality constrained assortment optimization problems.

## ■ SB22

North Bldg 130

**Joint Session RMP/Practice Curated: Data Science in Online Platforms**

Sponsored: Revenue Management &amp; Pricing

Sponsored Session

Chair: Ruben Lobel, Airbnb, San Francisco, CA, 94103, United States

Co-Chair: Carlos Abad, Airbnb, San Francisco, CA, 94103, United States

**1 - Supply-side Incentives Allocation at Lyft**

Davide Crippis, Lyft, San Francisco, CA, United States

Lyft runs a number of programs to engage drivers when and where supply is most needed. The aim is to align supply and demand, provide better service levels for passengers and increased earnings for drivers. Scientists work on optimizing these programs using machine learning, optimization algorithms, and continuous experimentation. We give an overview of different incentives programs and the technical problems they pose. We then present in more detail some of the techniques used to compute optimal allocations.

**2 - Zillow Instant Offers with Human-in-the-loop Machine-learning**

David E. Fagnan, Senior Manager, Applied Science, Zillow Group, Seattle, WA, United States, Fan Cao, Sebastian Wickenburg, Emily Gill, Krishna Rao

We give an overview of recent data science challenges at Zillow. In particular, we focus on Zillow Instant Offers, a new home-selling option for homeowners who want a certain and predictable sale on their timeline. Our system tries to balance offer quality, offer timeliness, and risk in the presence of potential selection bias. With this focus, we discuss our learnings around making decisions under uncertainty including examples such as how much to pay for a house, predicting housing liquidity through days on market, and how much a pool is worth. We discuss progress on these problems and how we combine the use of human judgement with machine-learning algorithms in a human-in-the-loop system.

### 3 - Marketplace Experimental Design at Airbnb

Ruben Lobel, Airbnb, 888 Brannan St, 3rd Floor - Airbnb,  
San Francisco, CA, 94103, United States, David Holtz, Bar Ifrach,  
Sinan Aral

Online A/B tests rely on the assumption that responses on treatment and control units are independent. However, experiments in online marketplaces such as Airbnb can be biased when listings in the treatment group affect the listings in the control group. We propose a method to reduce this bias by identifying a network of marketplace substitution and applying a clustering algorithm on this network. By delivering the experiment on clusters of listings, we hope to detect the true impact of our models, without sacrificing too much in the experiment's sample size. We demonstrate the use of this method with a pricing experiment, measuring the trade-off between bias reduction and statistical power.

### 4 - An Overview of Uber's Surge Pricing Mechanism

Hamid Nazerzadeh, USC Marshall School of Business, Bridge  
Memorial Hall - BRI 401B, 3670 Trousdale Parkway, Los Angeles,  
CA, 90089, United States

Uber is running one of the largest marketplaces in the world that matches millions of riders and drivers together. One of the key features of Uber's marketplace is dynamic pricing, so called surge pricing, that aims to balance the demand for trips and the supply of available cars. The surge pricing also motivates drivers to relocate to parts of the city with higher demand. In this talk, I'll discuss the design of the new generation of surge mechanisms that aim to increase the marketplace efficiency.

## SB23

North Bldg 131A

### Systemic Risk

Sponsored: Finance

Sponsored Session

Chair: Daniel Mitchell, University of Minnesota, Minneapolis, MN

Co-Chair: Stathis Tompaidis, University of Texas-Austin, Austin, TX,  
78712-1277, United States

### 1 - Regulation of Financial Networks

Daniel Mitchell, University of Minnesota, Minneapolis, MN,  
United States, Stathis Tompaidis

We investigate the problem faced by a regulator to impose capital constraints on financial institutions in a network. By imposing capital constraints on one bank, the riskiness of others may be affected. We show how the regulator can set cVaR capital requirements for every institution in the network simultaneously. We analyze this regulation and look at its implications in an example calibrated to match publicly available data from bank holding companies in the United States.

### 2 - Bank Risk Culture Identification by Machine Learning

Akena Owusu, Rensselaer Polytechnic Institute, Troy, NY,  
United States, Aparna Gupta

We develop a framework for evaluating the risk culture of banks and how it relates to banks' performance, governance and risk-taking incentives. Textual analytics of banks' annual 10-K reports using Loughran and McDonald's (2011) sentiment dictionary and a risk culture framework develops a two-dimensional features space. Legal expense as a proxy allows a feature reduction, followed by k-means clustering to group banks into three risk culture groups. The good and moderate risk culture groups show better performance, more institutional investors, lower total executive pay and equity fraction of pay. Boards of better risk culture groups have more independent directors.

### 3 - Can Swing Pricing Prevent Mutual Fund Runs and Fire Sales?

Agostino Capponi, Columbia University, 500 W. 120th street,  
New York, NY, 10027, United States

We develop a model of the feedback between mutual fund outflows and asset illiquidity. Alert investors anticipate the impact on the fund's NAV of other investors' redemptions and exit first at favorable prices. Our analysis shows that (i) the first-mover advantage introduces a nonlinear dependence between a market shock and the aggregate impact of redemptions on the fund's NAV; (ii) there exists a critical magnitude of the shock beyond which a run brings down the fund; (iii) properly designed (not swing pricing!) not only transfers liquidation costs from the fund to redeeming investors, but importantly reduces them and prevents fund failure.

### 4 - Managing Default Contagion in Inhomogeneous Financial Networks

Nils Detering, University of California, Santa Barbara, Santa  
Barbara, CA, 93106, United States

The aim of this paper is to quantify and manage systemic risk caused by default contagion in the interbank market. Our results allow us to determine the impact of local shocks to the entire system and the wider economy. As a central application, we characterize resilient and non-resilient cases. In particular, for the prominent case where the network has a degree sequence without second moment, we show that a small number of initially defaulted banks can trigger a

substantial default cascade. Paralleling regulatory discussions, we determine minimal capital requirements for financial institutions sufficient to make the network resilient to small shocks.

## SB24

North Bldg 131B

### Health IT Innovations: Opportunities and Risks

Sponsored: EBusiness

Sponsored Session

Chair: Idris Adjerid, University of Notre Dame, Notre Dame, IN, 46556,  
United States

### 1 - When IT Creates Legal Vulnerability: Not Just Overutilization but Underprovisioning of Healthcare Could be a Consequence

YeongIn Kim, University of Texas-Dallas, Richardson, TX, 75080,  
United States, Mehmet Ayvaci, Srinivasan Raghunathan,  
Turgay Ayer

There is a growing interest in better understanding the new IT vulnerabilities. We examine one such vulnerability, viz., the heightened litigation risk due to information sharing enabled by IT, in a typical health care context. Using a game-theoretic model, we find that socially optimal policies may require underprovisioning of health care in the presence of health IT. Limits on malpractice damage can alleviate the underprovisioning of health care.

### 2 - Detecting Anomalous Patterns of Care Using Health Insurance Claims

Sriram Somanchi, University of Notre Dame, 344 Mendoza College  
of Business, University of Notre Dame, Notre Dame, IN, 46556,  
United States, Edward McFowland, Daniel Neill

This work provides a novel machine learning methodology to identify subpopulations for whom certain patterns of medical care have led to significantly anomalous health outcomes. We detect interventions in patient care (currently in terms of medications) that have significantly affected health outcomes either negatively (in which case they may represent suboptimal care that should be identified and corrected) or positively (in which case they may represent new, previously undiscovered best care practices).

### 3 - Effect of Gamification on Healthful Activity: The Case of Fitbit Leaderboards

Idris Adjerid, Virginia Tech, Blacksburg, PA, 46556, United States,  
Zia Hydari, Aaron Striegel

Lack of physical activity represents a growing global health crisis. We evaluate whether gamification of health behavior using wearable devices is one intervention that has the potential to increase physical activity. Using a unique data set, our initial analysis suggests that gamification (in the form of leaderboards) leads to a significant increase in steps walked daily.

### 4 - Analyzing Healthcare Information Exchanges' Strategies in a Competitive Environment

Can Sun, University of Alberta, 03A Unit, 8909-112, Edmonton,  
AB, T6G 2C5, Canada, Yonghua Ji, Subodha Kumar

Demand for health information exchange (HIE) among healthcare providers is growing very fast. In this paper, we investigate a setting where heterogeneous healthcare providers can join one of two competing HIEs. The utility for a healthcare provider is determined by the software quality offered by an HIE and also the network effect, i.e., the number of healthcare providers adopting the same HIE. We use a game theoretical model to investigate how HIEs should price the basic and premium services to maximize their profits.

## SB25

North Bldg 131C

### Best Cluster Paper – II

Sponsored: Service Science

Sponsored Session

Chair: Paul R. Messinger, University of Alberta, University of Alberta,  
Edmonton, AB, T6G 2R6, Canada

### 1 - Service Science Best Cluster Paper

Paul R. Messinger, University of Alberta, University of Alberta,  
Edmonton, AB, T6G 2R6, Canada

This session consists of finalists presentations (judged by an expert panel) to determine the Service Science Section Best Cluster Paper.

## ■ SB26

North Bldg 132A

**Joint Session OR/Practice Curated: Doing Good with Good OR**

Emerging Topic: Doing Good with Good OR

Emerging Topic Session

Chair: Mehmet U.S. Ayvaci, University of Texas at Dallas, 800 W Campbell Rd, Sm33, Richardson, TX, 75080-3021, United States

Co-Chair: Gemma Berenguer, Purdue University, 1020 Happy Hollow Rd, West Lafayette, IN, 47906, United States

**1 - Influence Maximization for HIV Prevention among Homeless Youth**

Bryan Wilder, University of Southern California, Los Angeles, CA, United States

HIV among homeless youth is a pressing health challenge; hence, local agencies conduct HIV prevention interventions. Selected youth are trained as peer leaders and disseminate prevention-related information through their social network. Choosing influential peer leaders is a difficult optimization problem. Together with local agencies, we developed and deployed novel optimization techniques which reached over twice the youth as previous methods.

**2 - Inconvenience, Liquidity Constraints and the Adoption of Off-Grid Lighting Solutions**

Bhavani Shanker Uppari, INSEAD, 1 Ayer Rajah Avenue, Singapore, 138676, Singapore, Serguie Netessine, Ioana Popescu, Rowan Clarke

One-fifth of humankind living in poverty does not have access to electricity. An off-grid lighting model that is becoming prominent in impoverished countries is rechargeable bulb technology. We examine, both theoretically and empirically, the impact of liquidity constraints and recharge inconvenience on the usage of rechargeable bulbs. Our analysis has implications for both firm-level operational decisions and government-level policy decisions.

**3 - Improving the Chilean College Admissions System**

Ignacio Rios, Stanford University, Stanford, CA, 94305, United States

We designed and implemented a new white-box algorithm that solves the matching of students to universities, unifying the admission tracks and improving the allocation of around 2,500 students each year since it was fully implemented. In addition, our solution reduced dramatically the computational time, allowing the evaluation of other policies and the implementation of new changes to the Chilean college admissions system.

**4 - How and When Should Students Get to School? Equity-Driven Optimization for Boston Public Schools**

Sebastien Martin, Massachusetts Institute of Technology, Cambridge, MA, 02139, United States, Arthur Delarue

We collaborated with Boston Public Schools to develop and apply optimization algorithms for school bus routing and bell time assignment, resulting in a \$4+ million yearly educational reinvestment in a district where 75% of students are economically disadvantaged and the unanimous approval of the first equity-driven start time policy in almost thirty years by the Boston School Committee.

## ■ SB27

North Bldg 132B

**Joint Session Education/Practice Curated: INFORMS Case Competition**

Sponsored: Education (INFORMED)

Sponsored Session

Chair: Palaniappa Krishnan, University of Delaware, Newark, DE, 19716-2130, United States

**1 - You Can't Take It with You**

Coleen R. Wilder, Valparaiso University, 353 Sheffield Drive, Valparaiso, IN, 46383, United States, Sailu Li

The theme of this two-part case study is erroneous retirement planning experienced by two protagonists at different stages in their lives. A common retirement goal presented to many financial advisors is that people want to maintain their current lifestyles. For older clients, advisors are typically confronted with the task of explaining why their clients have insufficient funds and for younger clients, they are challenged with the task of convincing them to save more today for tomorrow. This case study provides a concrete example for students to visualize the impact of the time value of money. Students will often

nod their heads to the idea that a dollar today is not worth the same tomorrow. They also will nod to the fact that a loaf of bread costs more today than it did yesterday. It does not actually register, however, until they see it evolve year by year over an extended period of time. Advanced Excel functions that may be used include FV, PV, PMT, NORMINV, VLOOKUP, Scenario Manager, Data Table, and Goal Seek.

**2- Supply Chain Coordination and Contracts in the Sharing Economy: A Case Study at Cargo**

Maxime Cohen, NYU Stern, New York, NY, 10012, United States, Daniel Guetta, Wenqiang Xiao

This case study presents a modern approach to supply chain contracts. Supply chain coordination and supply chain contracts are central parts of almost every operations management (OM) core course. Traditionally, the main motivational example used in this context is video rentals. In the late 1990s, Blockbuster LLC revamped their business model and successfully implemented supply chain contracts. This is indeed an excellent example, but it is becoming increasingly outdated, and the vast majority of millennial students find it difficult to relate to this application. With this motivation in mind, we decided to revisit the topics of supply chain coordination and supply chain contracts in the context of the sharing economy. This case study is written in collaboration with Cargo, an innovative startup that recently raised \$7.3 million in seed funding, and illustrates how supply chain contracts can be applied in two-sided markets. Cargo sources goods from suppliers to provide a platform for gig economy drivers (e.g., Uber and Lyft) to run small convenience stores out of their vehicles. Consequently, Cargo needs to optimize its supply chain with both its drivers and its suppliers. Inspired by Cargo's operations, we generate datasets that illustrate the benefits of supply chain coordination and contracts, and allow students to experience the use of these techniques in a real-world business problem. This case study can be used at the undergraduate, MBA, and graduate levels for 1-3 sessions. In particular, instructors of an OM core or a supply chain elective course could use this case to discuss the following topics: (i) a novel OM application in the sharing economy, (ii) supply chain centralization, (iii) supply chain contracts (wholesale price, revenue sharing, and buyback), and (iv) the benefits of data-driven demand forecasting.

## ■ SB28

North Bldg 221A

**Joint Session RAS/Practice Curated: Railway Applications Section Student Paper Competition**

Sponsored: Railway Applications

Sponsored Session

Chair: Steven Harrod, Technical University of Denmark, Kgs. Lyngby, 2800, Denmark

**1 - Railway Applications Section Student Paper Competition**

Steven Harrod

Awards for the 2018 Railway Applications Section Student Paper Competitions will be presented, along with presentations by the finalists. Winners are announced at the conference, or a few weeks before at the earliest.

## ■ SB29

North Bldg 221B

**Business Models and Policies for Alternative Fuel Vehicle Deployment**

Sponsored: TSL/Urban Transportation

Sponsored Session

Chair: Sang Jin Kweon, Carnegie Mellon University, Pittsburgh, PA, 15206-3196, United States

**1 - Optimizing the Relocation Operations of Free-floating Electric-car Sharing Systems**

Zulqarnain Haider, University of South Florida, Tampa, FL, United States, Hadi Charkhgard, Sang Won Kim, Changhyun Kwon

In a free-floating electric-car sharing system, the problems of fleet placement to fulfill demand requirements, fleet recharging using limited infrastructure to fulfill recharging requirements, and driver pick up and delivery using shuttles are of great interest. In this work, we present a combined MILP formulation and a decomposition algorithm, to solve the aforementioned problems simultaneously, rather than sequentially. The relationship between preferred charging levels and geographic location of customer demand is used to determine recharging requirements.



## 2 - A Two-sided Ride-sharing Optimization Problem Considering Electric Vehicle Deployment

Sang Jin Kweon, Carnegie Mellon University, 5000 Forbes Ave, Pittsburgh, PA, 15213, United States

Ride-sharing platforms are online mobile platforms which match riders with drivers. As electric vehicles receive attention, the ride-hailing giant has dabbled in electric vehicle programs. In this talk, we address the ride-sharing problem to analyze the impacts of electric vehicle deployment on ride-sharing systems. A two-sided model for ride-sharing systems is formulated, and the closed-form solution is derived to maximize the ride-sharing platform's operating profitability. The numerical results are further discussed to quantify the impacts of deployment and utilization of electrified fleets in urban transportation systems.

## 3 - Evaluating and Optimizing Charging Strategies for Electrical Busses in Public Transportation Networks

Pieter van den Berg, Rotterdam School of Management, Erasmus University, Burgemeester Oudlaan 50, Rotterdam, 3062 PA, Netherlands, Ayman Abdelwahed, Tobias Brandt, John Collins, Wolfgang Ketter, Wolfgang Ketter

Public transport operators increasingly face a challenging problem in switching from conventional diesel to electrical busses. Cooperating with the public transport operator in the city of Rotterdam, we develop a discrete-event-based simulator to study the scheduling feasibility by applying different charging strategies. Some fundamental strategies are assessed such as "first in first served" and "lowest charge highest priority". A mixed integer linear programming optimization model is then introduced to obtain the optimal charging strategy, which showed better results.

## SB30

North Bldg 221C

## Collaborative and Flexible Logistics

Sponsored: TSL/Facility Logistics

Sponsored Session

Chair: Jennifer A. Pazour, Rensselaer Polytechnic Institute, Troy, NY, 12180, United States

## 1 - Towards a Collaborative Supply Chain: A Quantitative Approach to Shared Facility Design and Operations

Chase Rainwater, University of Arkansas, 4207 Bell Engineering Center, Fayetteville, AR, 72701, United States, Kimberly P. Ellis, William G. Ferrell, Philip Kaminsky

Supply chain experts agree that goods will move more quickly, require more customization, and be shipped to a more urbanized customer base over the next 25 years. The current logistics system makes inefficient use of transportation and storage resources. One answer to this growing problem is the adoption of a collaborative logistics system in which manufacturers, transporters, distributors and retailers make use of shared resources. This talk focuses specifically on how collaborative use of facilities should be approached operationally. A mathematical program is presented with results highlighting the differences in system operations from that seen in current logistics systems.

## 2 - Performance Analysis of Modern Goods-to-person Order Picking Systems

Francisco Jose Aldarondo, University of Michigan, 3512 Green Brier Boulevard, Apartment 497C, Ann Arbor, MI, 48105, United States

For many online retailers, order picking (OP) is a labor-intensive activity, and it typically accounts for over 50% of their operational costs. Although many online retailers use walk-and-pick systems, a stronger alternative is goods-to-person OP, which generally improves the picker efficiency and offers ergonomic advantages. In such systems, automated equipment brings the containers to the pick station(s) where picker(s) perform the picks. In this study, we are concerned with the performance analysis of state of the art good-to-person systems and the operational challenges they present.

## 3 - Flexible Supply Chain Network Design with Different Granularity Options

Kaan Unnu, Rensselaer Polytechnic Institute, Center For Industrial Innovation, 110 8th Street, Troy, NY, 12180-3590, United States, Jennifer A. Pazour

On-demand distribution matches underutilized capacity to entities who need distribution services on-demand. This enables finer commitment and capacity granularities, creates flexibility to address demand variability and volatility, but has higher variable costs. Our multi-period capacitated facility location problem simultaneously decides the best combination of distribution options (construction, long-term lease or on-demand). The proposed heuristic algorithm, combining p-median, decomposition, and column generation, is used to solve different scenarios and provide managerial insights.

## SB31

North Bldg 222A

## Advances in Routing and Network Algorithms

Sponsored: TSL/Intelligent Transportation Systems (ITS)

Sponsored Session

Chair: Mohamad Kamal El Din Ahmad Hasan, Kuwait University, Department of Quantitative Methods & IS, CBA, Kuwait City, 13055, Kuwait

## 1 - Mean-standard Deviation Model for Capturing Reliability in the Minimum Cost Flow Problem

Can Gokalp, University of Texas, Austin, TX, United States, Stephen D. Boyles

We study the mean-standard deviation network flow problem, where the objective is minimizing a linear combination of the mean and standard deviation of path costs. This optimization problem is non-linear and non-additive. We prove that the efficient frontier of this problem is a subset of the efficient frontier of the mean-variance problem. Leveraging this result we provide an algorithm that solves this problem by solving an easier mean-variance problem.

## 2 - Routing in Time-dependent Networks: A Microstate Interpretation of Dynamic Traffic Assignment

Mohammad Arani, PhD candidate, University of Arkansas, 7005 Archwood Dr., Little Rock, AR, 72204, United States, Yupo Chan

Dynamic traffic assignment suggests that, for the same origin and destination pair, a driver who departs later may reach her destination ahead of those who depart earlier. Although this has been shown, the result may be heavily dependent on the characteristics of a traffic network. Consider a directed graph  $G(N, A)$ , where the travel time and reliability of a commuting path varies over the day. For a risk-averse and a risk-prone driver, we wish to study the driver's behavior regarding different metrics. Included in the study is the ability for a driver to not only defer her departure time but also wait en-route for the traffic to clear. A computational study has been conducted on Central Arkansas network.

## 3 - Steep Roads Impact on Vehicle Routing Decisions

Ricardo Giesen, Associate Professor, Universidad Catolica de Chile, Vicuna Mackenna 4860 Macul, Casilla 306 Cod. 105, Santiago, Chile, Mathias A. Klapp, Carlos Brunner

Most routing decisions assume that the world is flat, however there are many cities in which this assumption does not hold. Thus, we formulated a Vehicle Routing Problem in regions with steep roads (VRP-sr), and implemented a heuristic solution method for this problem. We use this model to study the impacts of not taking into account steep road grades when routing vehicles which are visiting customers located at point with differences in altitude. Our initial results, show that in hilly cities cost reductions between 3% to 6% on average can be obtained when taking into account steep road grades. Moreover, there are instances in which cost reduction greater than 14% can be achieved.

## 4 - Online Routing of Heterogeneous Vehicles on Stochastic Time-Varying Managed Lane Networks

Priyadarshan Patil, University of Texas-Austin, 301 E. Dean Keeton Street, Stop C1761, Austin, TX, 78712, United States, Venktesh Pandey, Stephen D. Boyles

Managed lane (ML) networks have multiple entrances and exits, complicating the route choice decisions of travelers. Current algorithms in the literature either assume that travelers only compare a subset of alternatives or assume a value of time distribution which is difficult to calibrate. This presentation describes efficient algorithms exploiting the acyclic nature of the ML networks for optimal routing of vehicles given stochastic variation of toll and travel time values. We compare the performance of the algorithm against other methods and on larger networks.

## 5 - A Link Node Nonlinear Complementarity Model for a Multiclass Simultaneous Transportation Dynamic User Equilibria

Mohamad Kamal El Din Ahmad Hasan, Professor of Operations and Supply Chain Management, Kuwait University, Department of Quantitative Methods & Information Systems, College of Business Administration, Kuwait City, 13055, Kuwait, Xuegang Ban

In this paper, the authors combine a dynamic link-node based discrete-time Nonlinear Complementarity Problem (NCP) Dynamic Traffic Assignment (DTA) model with a static Multiclass Simultaneous Transportation Equilibrium Model (MSTEM) in a unified dynamic link-node based discrete-time NCP Dynamic Multiclass Simultaneous Transportation Equilibrium Model (DMSTEM) model. The new model improves the prediction process and eliminates inconsistencies that arise when the DTA or Dynamic Traffic Assignment with Departure Time (DTA-DT) is embedded in a more comprehensive transportation planning framework. An iterative solution algorithm for the proposed DMSTEM model is proposed.

## ■ SB32

North Bldg 222B

**Joint Session TSL/ICS: Approximate Dynamic Programming and Reinforcement Learning for Routing II**

Sponsored: TSL/Freight Transportation &amp; Logistics

Sponsored Session

Chair: Barrett Thomas, University of Iowa, Iowa City, IA, 52242-1000, United States

**1 - Reinforcement Learning for Solving the Vehicle Routing Problem**

Reza Nazari, Lehigh University, Bethlehem, PA, 18015, United States, Afshin Oroojlooy, Lawrence V. Snyder, Martin Takac

We present an end-to-end framework for solving Vehicle Routing Problem using reinforcement learning. In this approach, we train a single model that finds near-optimal solutions, only by observing the reward signals and following feasibility rules. Our model represents a parameterized stochastic policy, and by applying a policy gradient algorithm to optimize its parameters, the trained model produces the solution as a sequence of consecutive actions, without the need to re-train for every new problem instance. On capacitated VRP, our approach outperforms classical heuristics and Google's OR-Tools on medium-sized instances in solution quality with comparable computation time.

**2 - Reinforcement Learning for Same-day Delivery with a Heterogeneous Fleet of Drones and Vehicles**

Xinwei Chen, University of Iowa, Iowa City, IA, 52242, United States, Marlin Wolf Ulmer, Barrett Thomas

With ten cities approved in May to test drones, commercial use of drones is nearly a reality. Previous work shows, compared to a homogeneous fleet of vehicles, using a heterogeneous fleet of drones and vehicles for same-day delivery increases the expected number of served customers. In that work, a travel time-dependent threshold determines whether to dispatch a drone or a vehicle when both are available. In this talk, we introduce a time-dependent threshold to account for changing resource availability and heterogeneous customer requests. We use reinforcement learning to learn policies that are represented by neural networks. Computational results demonstrate improvements in solution quality.

**3 - Multi-Period Dynamic Technician Routing with Experience-based Service Times**

Barrett Thomas, University of Iowa, S210 PBB, Iowa City, IA, 52242-1000, United States, Mike Hewitt, Xi Chen

We study a multi-period technician routing problem in which technicians gain productivity as they gain experience. Tasks to be performed in the current day are known, but the tasks to be performed in subsequent days are uncertain. We develop an Approximate Dynamic Programming-based approach that incorporates into daily assignment decisions estimates of the long-term benefits associated with experience accumulation. Using an extensive computational study, we derive insights into how an organization can schedule their employees in a manner that enables meeting both near and long-term demands.

**4 - Multi-period Workload Balance in Last-mile Urban Delivery**

Yang Wang, Tsinghua University, Beijing, China, Lei Zhao, Martin W. P. Savelsbergh

When dispatching last-mile delivery among couriers, managers need to consider workload (im)balance among couriers besides their total travel cost. We differentiate two types of workload: incentive workload (e.g., number of packages) that affects couriers' income and effort workload (e.g., travel distance or time). We model the multi-period (e.g., a month) workload balance problem in last-mile delivery as a stochastic dynamic program and study the impact of various dispatching policies on the expected total travel cost and workload (im)balance.

## ■ SB33

North Bldg 222C

**Multimodal Passenger Transportation**

Sponsored: Transportation Science &amp; Logistics

Sponsored Session

Chair: Jan Fabian Ehmke, Otto-von-Guericke University, Magdeburg, 39106, Germany

**1 - Using Analytics to Find Reliable Itineraries for Multimodal Travel**

Michael Redmond, University of Iowa, 820 Spencer Dr, Iowa City, IA, 52246, United States, Ann Melissa Campbell, Jan Fabian Ehmke

Multimodal travel requires the combination of several transport options. In this presentation, we will introduce reliability measures of multimodal travel itineraries. These itineraries may include scheduled travel modes such as flights or buses as well as non-scheduled travel modes such as driving or ride-sharing

services to bridge the last mile. We base our reliability measures on continuous distributions of historical travel data and apply it to search for reliable itineraries. We also investigate the amount of historical travel data required to predict reliable itineraries.

**2 - Intermodal Autonomous Mobility on Demand Systems**

Maximilian Schiffer, Dr., Technical University of Munich, Munich, 52072, Germany, Mauro Salazar, Federico Rossi, Daniele Vigo, Christopher H. Onder, Marco Pavone

Currently, municipalities struggle to implement sustainable modes of transportation that can cope with increasing urban congestion. Against this background, we study the benefits of an autonomous mobility-on-demand system interacting with public transportation. We present a network flow model to jointly optimize the operation of a fleet of self-driving cars providing on-demand mobility and public transit. We design socially optimal control policies, including a pricing and tolling scheme to align the behaviour of selfish agents to the social optimum. Results on a case study of Manhattan show that such an intermodal system can yield significant benefits to an urban transportation network.

**3 - Considering Complex Customer Preferences in Multimodal Travel Itineraries**

Jan Fabian Ehmke, Otto von Guericke University, Universitätsplatz 2, Magdeburg, 39106, Germany, Thomas Horstmannshoff

Digital travel apps allow for easy combination of an ever-increasing number of multimodal travel options. However, underlying optimization approaches focus on simple objectives such as travel time, price or number of transfers, and neglect complex customer preferences that would provide a customer-oriented selection of multimodal travel itineraries. We highlight challenges of considering complex customer preferences in the creation of multimodal itineraries, present an overview of current research in this area, and, based on standard algorithms available in the literature, present a first solution approach that takes more complex preferences into account.

## ■ SB34

North Bldg 223

**11:00 - 11:45 JD.com/11:45 - 12:30 IBM**

Vendor Demo Session

**1 - Data Driven Supply Chain Management Practices at JD.com**

Zuo-Jun Max Shen, University of California Berkeley, 4141 Etcheverry Hall, Mail code 1777, Berkeley, CA, 94720-1777, United States

As China's largest retailer, online or offline, JD leverages advanced technologies such as AI to develop cutting-edge retail solutions that enable more personalized marketing and more efficient supply chain management, all aimed at improving the customer experience. In this tutorial, we will focus on a wide range of scenarios and applications in JD.com's ecosystem, from both JD's own e-commerce platform and its external business partners. We will cover the data-driven approaches used in these business scenarios to help improve supply chain efficiency and customer experience. We will also cover how technologies from fields such as operations research, data analytics, and machine learning are transforming the retail landscape.

**2 - Solving Multi-Objective problems with CPLEX**

Ed Klotz, IBM, P.O. Box 4670, Incline Village, NV, 89450, United States

During this tutorial, you will learn how to use the Multi-Objective feature in the upcoming version of CPLEX Optimizer. With the ability to specify combinations of lexicographic and blended objectives, it allows you to specify your goals very precisely. By using this feature, you can save the trouble of developing your own multi-objective framework, and avoid the numerical difficulties often faced when combining vastly different objectives scales.

## ■ SB35

North Bldg 224A

**Joint Session AAS/TSL-Air: Airport and Airspace Capacity**

Sponsored: Aviation Applications

Sponsored Session

Chair: Yuan Wang, University of South Florida, 6507 Markstown Dr, Tampa, FL

**1 - Dynamic Prediction of Runway Configuration and Airport Acceptance Rate**

Yuan Wang, University of South Florida, 6507 Markstown Dr, Tampa, FL, 33617, United States, Yu Zhang

Automated prediction of runway configuration and airport capacity is critical for the future generation of air traffic management. Airport Acceptance Rate (AAR) is a key parameter to measure capacity in Ground Delay Program, and runway configuration is prerequisite to determine or adjust AAR. In this study, different weather forecast information was collected, decoded and then integrated. Then we proposed a time-dependent data-driven deep learning mechanism to predict runway configuration and Airport Acceptance Rate (AAR) simultaneously from the multi-source weather forecast, as well as airport condition and air traffic demand.

**2 - En-route Flow Corridor Capacity with a Dynamic Wake Separation Policy**

Azin Zare-Noghabi, George Mason University, Fairfax, VA, United States, John Shortle

To prevent en-route wake encounters, aircraft must maintain adequate separation. Current separation requirements are static. This talk investigates a dynamic wake separation concept where separation requirements are updated using real-time meteorological and aircraft-state data. This allows separation requirements to be specified based on more precise state information, rather than using pessimistic assumptions. A simulation of an en-route flow corridor is presented and capacity benefits are discussed under a variety of traffic scenarios.

**3 - Ground Delay Program Planning with Uncertain Airport Capacity**

Jun Chen, San Diego State University, San Diego, CA, 92182, United States

To efficiently balance traffic demand and capacity, ground delay program (GDP) planning rely on accurate predictions of future airport capacity. However, these predictions are inherently uncertain due to factors such as weather. This work will present a robust method to incorporate probabilistic information of capacity for GDP planning with chance constraints. The idea is to constrain the chance of a capacity constraint violation, based on probabilistic information about future capacity prediction. The major advantage is to provide robust solutions with user-defined service level, which can be adjusted by the air traffic authority or airlines to ensure reliable operations.

**4 - Optimizing Flight Schedules for Minimum Delay**

Rajesh Piplani, Nanyang Technological University, School of MAE, 50 Nanyang Avenue N3-2C-84, Singapore, 639638, Singapore, Wai Lun Cheung

In order to minimize the imbalance between capacity and demand, the airports managers negotiate with the airlines the flight schedules months ahead of time. In this research, we propose an integrated approach to optimize the daily flight schedules in light of the delays likely to be encountered on the day of actual flights; we estimate the delays from sequences of flight movements, optimized dynamically and continuously during the peak period of operations. Our proposed integrated approach would better estimate the delays likely to be encountered, and the resulting schedule interventions by airport managers (developed on the basis of a dynamic programming model) that can reduce those delays.

## ■ SB36

North Bldg 224B

**Airline Competition and Customer Choice**

Sponsored: Aviation Applications

Sponsored Session

Chair: Susan Hotle, Virginia Tech, Blacksburg, Virginia

**1 - The Evolution of Low-Cost Carrier Operational Strategies Pre- and Post-Recession**

Susan Hotle, Virginia Tech, Blacksburg, VA, 24061, United States, Stephanie Atallah, Stacey Mumbower

This study analyzes LCC competition strategies for CONUS markets. Using OAG schedules, pre- and post-recession trends in LCC flight offerings were compared with their major carrier counterparts in terms of markets served, flight frequency, and competition structures of served markets. Results show that LCCs increased

the number of markets served to/from large airports. The results suggest that LCCs outpaced major carriers in terms of markets entered while major carriers have gained a greater flight frequency share in the markets they already serve. However, evidence suggests that the top four LCCs adopted different operating strategies during the study period.

**2 - Predicting Demand for Intra-urban Air Taxi Service**

Laurie A. Garrow, Georgia Institute of Technology, School of Civil &amp; Environmental Engr, 790 Atlantic Drive, Atlanta, GA, 30332-0355, United States, Robert Binder, Sreekar-Shashank Boddupalli, Thomas Douthat, Brian German

Imagine a world where instead of sitting in traffic on the downtown connector, you could simply drive to a vertiport near your home, enter into a small electric propulsion aircraft, fly over traffic, land on a rooftop near your work, and either walk or have an rideshare vehicle take you to your office. In this presentation, we provide an overview of ongoing research in air taxi flights for cities and present results from a survey we conducted of 2,500 commuters in five cities in the U.S. to estimate commuting demand and willingness to pay for these air taxi flights.

**3 - How Frequent Flyers Choose Airlines Case of Turkey**

Ozay Ozaydin, Dogus University, Zeamet Cad. No:21, Istanbul, 34722, Turkey

Airline industry can easily be considered to have the fiercest competition among businesses, due to the sensitive nature of customer trends. Thus, airline companies do and must dynamically adapt a number of competitive strategies in order to survive in this market and also expand their share. These strategies include these main topics: pricing, on-time performance, passenger satisfaction, luggage handling, flight safety and corporate image. The common dominator for all these topics is customer focus. The airline passengers' selection principles are used for main criteria for a comparison of airlines operating in Turkey.

## ■ SB37

North Bldg 225A

**Control and Analysis of Queueing Systems**

Sponsored: Applied Probability

Sponsored Session

Chair: Guodong Pang, Penn State University, University Park, PA, 16802, United States

**1 - Stability of a Standard Decentralised Medium Access**

Aleksandr Stolyar, University of Illinois at Urbana-Champaign, 1308 W. Main Street, Office 156CSL, Urbana, IL, 61801, United States, Vsevolod Shneer

A decentralised medium access algorithm is considered. Each node generates packets at the rate  $\lambda$ . Each packet takes one time unit (slot) to transmit. There are no collisions - neighbouring nodes cannot transmit simultaneously. The algorithm we study is standard in that: a node with empty queue does not compete for access; the access procedure by a node does not depend on its queue length, as long as it is non-zero. For two system topologies, with nodes arranged in a circle and in a line, we prove the system stochastic stability under the condition  $\lambda < 2/5$ . This result is intuitive for the circle topology (which, however, does not help to prove it), but not intuitive at all for the line topology.

**2 - Optimal Service Elasticity in Large Scale Distributed Systems**

Debankur Mukherjee, Eindhoven University of Technology, Heeghtakker 78A, Eindhoven, 5625SW, Netherlands, Sem Borst, Souvik Dhara, Johan S. van Leeuwen, Aleksandr Stolyar

A fundamental challenge in large-scale systems is to achieve efficient server utilization and limit energy consumption, while providing excellent performance. We propose a joint auto-scaling and load balancing scheme, which does not require any global queue length information or explicit knowledge of system parameters, and yet provides provably near-optimal service elasticity. Specifically, we prove that both the waiting time of tasks and the relative energy consumed by idle servers vanish in the limit. At the same time, the proposed scheme operates in a distributed fashion and involves only constant communication overhead per task, ensuring scalability in massive data center operations.



### 3 - Analysis of Processor Sharing Queues via Relative Entropy

Amber L. Puha, California State University-San Marcos,  
Department of Mathematics, 333 S. Twin Oaks Valley Road,  
San Marcos, CA, 92096-0001, United States, Ruth J. Williams

In this talk, we discuss a new approach to studying the asymptotic behavior of fluid model solutions (formal functional law of large numbers limits) for critically loaded processor sharing queues. For this, we introduce a notion of relative entropy associated with measure valued fluid model solutions. This approach is developed with idea that similar notions involving relative entropy may be helpful for understanding the asymptotic behavior of critical fluid model solutions for stochastic networks operating under protocols naturally described by measure-valued processes.

### 4 - Ergodicity Properties of Levy-driven SDEs Arising from Multiclass Many-server Queueing Networks

Guodong Pang, Penn State University, 310 Leonhard Bldg.,  
Industrial and Manufacturing Engineering, University Park, PA,  
16802, United States

We study the ergodic properties of multidimensional piecewise Ornstein-Uhlenbeck processes with jumps, arising in multiclass many-server queues with bursty arrivals and/or asymptotically negligible service interruptions in the Halfin-Whitt regime. The SDEs have a piecewise linear drift, and are driven by either (1) a Brownian motion and a pure-jump Levy process, or (2) an anisotropic Levy process with independent one-dimensional symmetric alpha-stable components, or (3) an anisotropic Levy process as in (2) and a pure-jump Levy process. We identify conditions on the parameters in the drift and the Levy measure which result in polynomial and/or exponential ergodicity.

## SB38

North Bldg 226B

### Recent Developments in Load-balancing Algorithms

Sponsored: Applied Probability

Sponsored Session

Chair: Anton Braverman, Northwestern University, Evanston, IL,  
60208, United States

#### 1 - Asymptotically Optimal Load Balancing Topologies

Debankur Mukherjee, Eindhoven University of Technology,  
Heeghtakker 78A, Eindhoven, 5625SW, Netherlands, Sem Borst,  
Johan S. van Leeuwen

We consider a system of  $N$  servers inter-connected by some graph topology  $GN$ . Tasks with unit-mean exponential service times arrive at the various servers as independent Poisson processes of rate  $\lambda$ . Each incoming task is assigned to whichever server has the smallest number of tasks among the one where it appears and its neighbors in  $GN$ . This model has been extensively investigated via mean-field techniques in the case  $GN$  is a clique. For arbitrary graph, mean-field techniques breakdown, complicating the analysis. In this talk we will investigate how much sparsity in the graph can be allowed maintaining the asymptotic behavior of a clique on a fluid and a diffusion scale.

#### 2 - Stein's Method for Mean-field Approximations

Lei Ying, Arizona State University, Chandler, AZ, United States

Mean-field analysis is an analytical method for understanding large-scale stochastic systems such as large-scale data centers and communication networks. Most existing mean-field models concerned the light-traffic regime where the load of the system is strictly less than one and is independent of the size of the system. To overcome this difficulty of traditional mean-field models, this paper views the equilibrium point of the mean-field model, called a mean-field solution, simply as an approximation of the stationary distribution of the finite-size system, and uses Stein's method to quantifies the approximation errors.

#### 3 - A Simple Steady-State Analysis of Load Balancing Algorithms in the Sub-Halfin-Whitt Regime

Xin Liu, Arizona State University, Tempe, AZ, 85281,  
United States, Lei Ying

This work studies a class of load balancing algorithms for many-server systems assuming finite buffer. We focus on the steady-state performance of load balancing algorithms in the heavy traffic regime (called sub-Halfin-Whitt regime). We establish a sufficient condition under which the probability that an incoming job is routed to an idle server is one asymptotically. The class of load balancing algorithms that satisfy the condition includes join-the-shortest-queue (JSQ), idle-one-first (IIF), join-the-idle-queue (JIQ), and power-of-d-choices (Pod) with certain  $d$ . The proof of the main result is based on the framework of Stein's method. A key contribution is to use a simple generator approximation based on state space collapse.

### 4 - Steady-state Analysis of the Join the Shortest Queue Model in the Halfin-Whitt Regime

Anton Braverman, Northwestern University, Kellogg Global Hub,  
Room 4171, Evanston, IL, 60208, United States

This talk will focus on the generator comparison framework. This framework also goes by the name of the Stein method framework or the drift-based fluid Lyapunov function approach, and has received significant attention over the past few years as a tool for proving rates of convergence to steady-state fluid and diffusion approximations. I focus on the Join the Shortest Queue (JSQ) model in the Halfin-Whitt regime. This is an example of a 'clean' application of the generator comparison framework, which lets one push the boundaries of what the framework can do. Two specific points include a novel 'trick' to deal with state space collapse, and an approach to prove exponential ergodicity for Markov processes.

## SB39

North Bldg 226A

### Large-scale Data Centers

Sponsored: Applied Probability

Sponsored Session

Chair: Siva Theja Maguluri, ISyE Ba Tech, Atlanta, GA, 30339,  
United States

#### 1 - Adaptive Matching for Expert Systems with Uncertain Task Types

Virag Shah, Stanford University, Stanford, CA, United States,  
Lennart Gulikers, Laurent Massoulié, Milan Vojnovic

Online two-sided matching markets such as Q&A forums (e.g. StackOverflow, Quora) and online labour platforms (e.g. Upwork) rely on the ability to propose adequate matches based on imperfect knowledge of the two parties to be matched. This prompts a question: Which matching algorithms can, in the presence of uncertainty, lead to efficient platform operation? To this end, we develop a model of a task-server matching system. We give a necessary and sufficient condition for an incoming stream of tasks to be manageable by the system. We identify an optimal policy and show that it outperforms a natural greedy policy. We confirm our theoretical findings with experiments based on logs of a StackOverflow forum.

#### 2 - Small-scale Markets for Bilateral Resource Trading in the Sharing Economy

Srinivas Shakkottai, Texas A&M University, Dept. of ECE, College  
Station, TX, United States, Bainan Xia, Vijay Subramanian

We consider a small-scale market for agent-to-agent resource sharing, in which each agent could either be a server (seller) or a client (buyer). In every time period, a server has resources that any client could consume, and randomly gets matched with a client. During each transaction, the server gets money and the client gets resources. We model the system using a Mean Field Game approach and prove the existence of the Mean Field Equilibrium, which can achieve an almost 100% trade ratio. Finally, we carry out a simulation study motivated by an agent-to-agent computing market, and a case study on a proposed photovoltaic market, and show the designed market benefits both individuals and the system as a whole.

#### 3 - Integrating Online Learning and Adaptive Control in Queueing Systems with Uncertain Payoffs

Xiaojun Lin, Professor, Purdue University, 465 Northwestern Ave.,  
EE Building, West Lafayette, IN, 47907, United States,  
Wei-Kang Hsu, Jiaming Xu, Mark R. Bell

Consider a queueing system where un-labeled clients arrive according to a stochastic process and each client brings a random number of tasks. As tasks are assigned to servers, they produce client/server-dependent random payoffs. The goal of the system is to maximize the expected payoff per unit time subject to the servers' capacity constraints. However, both the statistics of the dynamic client population and the client-specific payoff vectors are unknown to the operator. We design task-assignment policies that carefully integrate adaptive control (of the queueing system) with online learning (of the clients' payoff vectors) to achieve low regret in finite time.

#### 4 - Risk-sensitive Optimal Control of Stochastic Networks

Rahul Singh, Intel, Santa Clara, CA, United States

We consider the problem of designing risk sensitive optimal control policies for scheduling in a stochastic network. A single server provides service to  $N$  queues. Processing incurs a cost of  $C$  units, while completion yields a reward of  $R$  units. The queues have a buffer capacity of  $B$  units, and are penalized  $L$  units if a job is lost due to buffer overflow. We show that the risk-sensitive optimal control policy for such a simple set-up is of threshold type.

## ■ SB40

North Bldg 226B

### Statistical and Optimal Learning

Sponsored: Applied Probability

Sponsored Session

Chair: Ilya O. Ryzhov, University of Maryland, College Park, MD, 20742, United States

#### 1 - The Diverse Cohort Selection Problem

John P. Dickerson, University of Maryland, 3217 A.V. Williams Building, University of Maryland, College Park, MD, 20742, United States

How should a firm allocate its limited interviewing resources to select the optimal cohort of new employees from a large set of job applicants? How should that firm allocate cheap but noisy résumé screenings and expensive but in-depth in-person interviews? We view this problem through the lens of combinatorial pure exploration (CPE) in the multi-armed bandit setting, where a central learning agent performs costly exploration of a set of arms before selecting a final subset with some combinatorial structure. We present new algorithms with theoretical guarantees and provide experimental validation on real data from a hiring process at a large US-based graduate program.

#### 2 - Data-driven Decision-making Using Variational Bayes

Harsha Honnappa, Purdue University, West Lafayette, IN, United States

We consider a canonical problem where an agent uses Bayesian updating to learn to take optimal actions from independent and identically distributed (i.i.d.) observations of the state of a stochastic system. Given these observations, beliefs over unknown state parameters are summarized by a posterior distribution, allowing decision-making which, while Bayes-optimal, is typically computationally intractable. In this talk, we present asymptotic and empirical analyses of two algorithms for learning optimal decision-rules, which we call naive variational Bayes (NV) and loss-calibrated variational Bayes (LC) algorithms for data-driven decision-making.

#### 3 - Index Policies and Performance Bounds for Dynamic Selection Problems

David Brown, Duke University, Fuqua School of Business, 100 Fuqua Drive, Durham, NC, 27708, United States, James E. Smith

In this work, we study heuristics and performance bounds for dynamic selection problems. Examples of dynamic selection problems include assortment planning with demand learning, design of clinical trials, and screening a pool of applicants (e.g., for admission to colleges). We study a number of index-based policies, including one based on a Lagrangian relaxation of the problem. We characterize the performance of this Lagrangian index policy compared to an optimal policy. We also develop performance bounds that combine Lagrangian relaxations with information relaxations and show that these new performance bounds outperform standard Lagrangian relaxation bounds.

#### 4 - A New Rate-balancing Algorithm for Ranking and Selection

Ye Chen, 1305 Mathematics Building, University of Maryland, College Park, MD, United States, Ilya O. Ryzhov

Recent years have seen a surge of interest in the study of optimal convergence rates in ranking and selection, based on the large deviations approach of Glynn & Juneja (2004). We present a new algorithmic and computational approach that adaptively learns the optimal allocations derived by Glynn & Juneja (2004) without any tunable parameters. Our proposed BOLD (Balancing Optimal Large Deviations) method assumes that the samples come from a known distributional family, but is applicable and quite easy to implement for multiple families (in particular, it does not require normality). We report our progress on the theoretical analysis of BOLD and present preliminary numerical results.

## ■ SB41

North Bldg 226C

### Joint Session DAS/Practice Curated: Decision Analysis Practice Award Competition

Sponsored: Decision Analysis

Sponsored Session

Chair: Saurabh Bansal, Penn State University, State College, PA, 16801, United States

Co-Chair: Michael C. Runge, USGS Patuxent Wildlife Research Center, 12100 Beech Forest Rd, Laurel, MD, 20708, United States

Co-Chair: Michael Fitch, Chevron, San Ramon, CA, 9458, United States

#### 1 - Modeling the Value of Agents in Supply Chains of Malaria Rapid Diagnostic Test Kits with Decision Analysis

Jarrod D. Goentzel, Massachusetts Institute of Technology, 77 Massachusetts Avenue, E38-650, Cambridge, MA, 02139, United States, Gilberto Montibeller, Corinne Carland

Malaria poses one of the greatest challenges to global health. Accurate diagnosis, with rapid diagnostic tests (RDTs), is critical because presumptive treatment of malaria wastes resources and increases the risk of drug resistance. In this project, we developed a value model for the agents along the RDT kit supply chain in Uganda. The model, based on multi-attribute value theory, enables an understanding of the motivations of each agent in the supply chain. The analysis identified a new package of incentives that proved to be robust against the variation of relevance of agents in the chain.

#### 2 - New Methods for Improved Decision Making in Unconventional Field Development

Andrew Beck, University of Texas-Austin, Austin, TX, 78757, United States, J. Eric Bickel

We developed a decision support tool for Statoil's US Onshore portfolio. This tool includes an asset valuation model and price and production uncertainty models. Because of high dimensionality, finding an optimal dynamic development schedule based on learning is difficult. We combined the Least Squares Monte Carlo algorithm with forward simulation to replicate an annual cycle of drilling, learning, and adaptation. By finding the set of alternatives that yields the highest net present value, the user ends up with an expected NPV for the asset, and a recommended year 1 development plan.

#### 3 - Safer Skies in Spain

David Rios Insua, ICMAT-CSIC and Royal Academy of Sciences, Nicolas Cabrera 13, Madrid, 28049, Spain, Javier Gómez, Carlos Alfaro, Verónica Elvira, Pablos Hernández-Coronado, Fran Bernal

As required by the International Civil Aviation Organization, nations must develop a so-called State Safety Program (SSP) to promote a proactive approach to safety oversight and management at country level. SSPs support strategic decision-making and resource allocation to areas with higher aviation safety risks. The Spanish Aviation Safety and Security Agency (AESA) developed a novel methodology with full use of numerous Decision and Data Sciences methods and implemented it in an R-based tool. This has allowed AESA to better support its safety decision making and attain considerable savings.

## ■ SB42

North Bldg 227A

### Joint Session ISim/APS: Simulation Optimization II

Sponsored: Simulation

Sponsored Session

Chair: David Eckman, Cornell University, Cornell University

Co-Chair: Shane Henderson, Cornell University

#### 1 - Sequential Inferential Optimization via Simulation Under Input Model Risk

Eunhye Song, Penn State University, 310 Leonhard Building, University Park, PA, 16802, United States

Optimization via simulation (OvS) is subject to model risk when the input distributions to the simulator are estimated based on finite real-world data. We sequentially fit a Gaussian process metamodel to the conditional means of solutions as a function of the input model parameters and the design parameters to assist OvS and define a solution to be inseparable from the real-world optimum if the expected improvement (EI) of the solution's conditional mean is less than a threshold specified by a user. At each iteration, we compute EIs of all solutions to form a set of inseparable solutions from the optimum. We simulate a solution that can best reduce the size of the set until a stopping criterion is met.

#### 2 - Simple Top-two Sampling Algorithms for Best-arm Identification

Daniel Russo

This talk considers the optimal adaptive allocation of measurement effort for confidently identifying the best among a finite set of options or designs. I propose top-two sampling, a template for designing algorithms that adaptively allocate measurement effort. Four simple Bayesian algorithms designed via this template are shown to have strong performance in numerical experiments, and a unified analysis establishes each satisfies strong asymptotic optimality properties.

#### 3 - A Knockout-tournament Approach to Large-scale Indifference-zone Ranking and Selection

Ying Zhong, City University of Hong Kong, 22 Cornwall Street, KLN Tong, KLN, Hong Kong, L. Jeff Hong

Ranking and selection is similar to a sport tournament where the goal is to find a champion. Traditional R&S procedures typically compare the best with all competing K-1 alternatives. Motivated by the form of knockout tournaments typically used in tennis grand slams, we propose a R&S procedure where the best only needs to survive log<sub>2</sub> K comparisons. We show that the procedure works well for large-scale problems and is particularly suitable for commercial cloud services.

#### 4 - Comparing Frequentist and Bayesian Fixed-Confidence Guarantees for Selection-of-the-Best Problems

David J. Eckman, Cornell University, 118 Compton Rd, Ithaca, NY, 14850, United States, Shane Henderson

The problem of selecting the best from among a finite number of simulated alternatives has been studied under the contrasting frequentist and Bayesian interpretations of probability. We emphasize the conceptual differences in fixed-confidence guarantees under the two frameworks and examine practical implications of this distinction. We also discuss how frequentist selection procedures are inherently conservative and Bayesian selection procedures are relatively easier to design. Through simulation experiments, we compare the performance of selection procedures designed under each framework with respect to the other type of guarantee.

#### ■ SB43

North Bldg 227C

#### Joint Session Energy/Climate & ENRE/Env: Renewable Energy and Storage Modeling and Policy for the US

Emerging Topic: Energy and Climate

Emerging Topic Session

Chair: Zana Cranmer, Bentley University, Waltham, MA, 02452, United States

##### 1 - Dispatch of Wind, Solar, and Energy Storage in Long-term Planning Models

Cara Marcy, Renewable Electricity Analyst, U.S. Energy Information Administration, 1000 Independence Avenue SW, Washington, DC, 20585, United States

EIA's National Energy Modelling System (NEMS) provides a detailed multi-decadal assessment of the future of U.S. energy sectors. With the recent growth of wind and solar technologies, EIA has been working on capturing the value of these resources given their variable nature. In addition, energy storage is one technology that can take advantage of value streams presented from curtailment of excess renewable energy. This presentation will review the updated mini-dispatch model in NEMS, as well as highlight scenario results that investigate the relationship between renewable energy and storage.

##### 2 - The Potential for Emissions Reductions with Residential Demand Response

Maddie Macmillan, North Carolina State University, Raleigh, NC, United States, Jeremiah Johnson

The primary goal of demand response (DR) is to reduce peak electricity demand. In this study, we examine an alternative goal of using DR to reduce air emissions. For the US, we estimate the diurnal and seasonal demand profiles for suitable residential end uses including air conditioning, electric heating, and water heating. We assume that the DR events are load-neutral and test a range of tolerances for demand deferral. We develop an emissions minimization model that utilizes hourly marginal emissions factors for 20 grid regions to show significant potential to reduce CO2 emissions through DR approaches. The magnitude of the benefits are limited by the length of the demand deferral and DR adoption rate.

##### 3 - Estimating the Value of Offshore Wind Along the United States' Eastern Coast

Andrew Mills, Research Scientist, Lawrence Berkeley National Lab., 1 Cyclotron Rd., Berkeley, CA, 94720, United States

Offshore wind has been concentrated in Europe, and remains limited in other areas of the world. Among the many challenges to deployment is the need to understand the value that offshore wind provides within electricity markets. To explore the drivers of offshore wind value we use historical (2007-2016) weather data at thousands of potential offshore wind sites, combined with historical wholesale electricity market outcomes at hundreds of possible interconnection points. We find that the average historical market value of offshore wind from 2007-2016 varies significantly by project location, from \$40/MWh to more than \$110/MWh, and is highest for sites off of NY, CT, RI, and MA.

##### 4 - The Climate Value of Offshore Wind Energy in the US

Zana Cranmer, Bentley University, 175 Forest Street, Waltham, MA, 02452, United States, Erin Baker

We develop a forward looking method for estimating the value of permitting offshore wind projects in terms of addressing climate change. Offshore wind provides an additional way to reduce emissions as well as potential reductions in the cost of abatement. Our method includes value from both sources using the GCAM-USA model to look at different regions of the world and the US. These values can be compared to the potential costs imposed on local ecosystems.

#### ■ SB44

North Bldg 227C

#### Joint Session ENRE/Practice Curated: Optimization Methods for Power Systems

Sponsored: Energy, Natural Res & the Environment/Electricity

Sponsored Session

Chair: Cedric Josz

Co-Chair: Somayeh Sojoudi, University of California, Berkeley, Berkeley, CA, 94703, United States

##### 1 - Learning Solutions to Optimal Power Flow: An Active Set Approach

Line Roald, University of Wisconsin-Madison, Madison, WI, United States, Sidhant Misra, Yee Sian Ng

Power systems optimization involves solving similar optimization problems over and over and over again, with slightly varying input parameters. We consider the problem of directly learning the optimal solution as a function of the input parameters. Our learning framework is based on identifying the relevant set of active constraints, which we discover using our proposed streaming algorithm with performance guarantees. Applying the algorithm to the optimal power flow problem with renewable energy, we establish that the number of active sets is typically small for OPF problems, and discuss theoretical and practical implications for power systems operation.

##### 2 - Improving Bound Tightening with Quadratic Reformulation Method Applied on Optimal Power Flow

Hadrien Godard, Rte, Paris, France

Optimality-based and reduced-costs bound tightening are classic methods using convex relaxations. For the OPF problem, the Quadratic Reformulation method gives an efficient relaxation, leading to sharp lower bounds, and interior-points methods compute good feasible solutions. We strengthen bound tightening using those sharp bounds, and present computational results on OPF instances up to a thousand nodes.

##### 3 - Tight Piecewise Convex Relaxations for Global Optimization of Optimal Power Flow

Harsha Nagarajan, Los Alamos National Laboratory, NM, United States, Mowen Lu, Russell Bent, Sandra D. Eksiöglu, Kaarthik Sundar

In recent years, there has been an increasing interest in developing convex relaxations for ACOPF, which are often tight in practice. We further improve the quality of these relaxations by employing convex-hull characterizations for multilinear functions and develop tight piecewise convex relaxations. We also provide useful polyhedral results of these relaxations. Using these tight relaxations, we develop an adaptive, multivariate partitioning algorithm with bound tightening that progressively improves these relaxations, thus converging to the global optimal solution. Computational results show that our novel algorithm reduces the best-known optimality gaps of the NESTA ACOPF cases.

##### 4 - Conic Optimization for Robust State Estimation: Deterministic Bounds and Statistical Analysis

Igor Molybog, University of California, Berkeley, Berkeley, CA, United States, Ramtin Madani, Javad Lavaei

This project is concerned with the robust electric power system state estimation problem, where the goal is to find the unknown state of a system modeled by nonconvex quadratic equations based on unreliable data. We propose two techniques based on conic optimization to address this problem. We analyze the techniques in both deterministic and stochastic (Gaussian) settings by deriving bounds on the number of bad measurements the algorithms can tolerate without producing a nonzero estimation error. The efficacy of the developed methods is demonstrated on synthetic data and the European power grid.



## ■ SB45

North Bldg 228A

### Real-time Optimization in Power Networks

Sponsored: Energy, Natural Res & the Environment/Electricity  
Sponsored Session

Chair: Enrique Mallada, Johns Hopkins University, Baltimore, MD, 21218, United States

Co-Chair: John Simpson-Porco, University of Waterloo-ECE Department, Waterloo, ON, N2L 3G1, Canada

#### 1 - A System Level Approach to Frequency Control

Nikolai Matni, UC Berkeley, Berkeley, CA, United States

We show how the System Level Approach to controller design can be used to explore design tradeoffs in primary and secondary frequency control. In particular, we show that localized distributed optimal controllers can be computed and implemented at scale, and explore tradeoffs in system performance, robustness, actuation density, sampling time, communication speed, and coordination between subcontrollers. We end with a brief discussion of progress made towards co-designing such low-level feedback, or reflex, layers and higher-level planning layers, such as those solving optimal power-flow problems.

#### 2 - Optimal Steady State Control for Frequency Regulation

John Simpson-Porco, University of Waterloo, 200 University Avenue West, Waterloo, ON, N2L 3G1, Canada, Liam S. Lawrence, Zachary Nelson, Enrique Mallada

We consider the problem of designing a feedback controller that guides the input and output of a linear time-invariant system to a minimizer of a convex program in the presence of unknown disturbances. The proposed controller combines proportional-integral control with gradient feedback, and enforces the KKT optimality conditions in steady-state, without incorporating dual variables into the controller. The results are applied to derive different centralized and distributed secondary frequency regulation strategies for power systems.

#### 3 - Online Optimization with Feedback for Power Grids

Emiliano Dall'Anese, University of Colorado Boulder, CO, United States

This talk addresses the design of feedback-based online algorithms for distribution systems. The time-varying optimization formalism is leveraged to model optimal operational trajectories of a distribution system, as well as explicit local and network-level operational constraints. The design of the algorithms capitalizes on an online implementation of primal-dual projected-gradient methods; the gradient steps are modified to accommodate measurements from the system. The algorithms can cope with model mismatches, avoid pervasive measurements, and lend themselves to distributed implementations. Convergence claims are established in terms of dynamic regret and Q-linear convergence.

#### 4 - The Effect of Power System Dynamics on Feedback Steady-state Optimization

Adrian Robert Hauswirth, ETH Zurich, ETL I. 13, Physikstrasse 3, Zurich, 8092, Switzerland

We consider the problem of optimizing the steady-state of a power system in closed loop. While the design of the feedback steady-state optimization law is based on a time-scale separation argument, in reality the dynamics of the (slow) iterative optimization routines can interfere with the (fast) natural system dynamics (e.g. primary frequency control). We provide a study of the stability and convergence of these optimization routines when applied to power systems, and we suggest solutions to maximize the robustness of these methods with respect to the underlying power system dynamics.

## ■ SB46

North Bldg 228B

### Decisions in Energy Markets using Extended Concepts of Equilibrium

Sponsored: Energy, Natural Res & the Environment/Energy  
Sponsored Session

Chair: Sauleh Ahmad Siddiqui, Johns Hopkins University, Baltimore, MD, 21218, United States

#### 1 - Demand Response by Load and EV Aggregators Linked by an Option Contract for Load Sharing

Kevin Melendez, University of South Florida, Tampa, FL, 33613, United States, Tapas K. Das, Changhyun Kwon

With the increasing penetration of electric vehicles (EVs) on the market, the coordinated control of a large fleet of EVs by an aggregator has obtained special attention in the last decade. The cooperation among the EV aggregators and other demand response agents must be addressed to adequately incorporate this new player into the electricity market. In this work, we proposed an option contract among the EV aggregator and a demand response aggregator to define the

economical agreement between the players. The resulting problem was solved using the Nash bargaining solution.

#### 2 - Multicriteria Decision Analytic Framework for Evaluating Future Power Generation Pathways

Thushara De Silva, PhD Candidate, Vanderbilt University, 105 Jefferson Square, Nashville, TN, 37215, United States, George M. Hornberger, Hiba Baroud

Power generation planning objectives are reliable power system, economic efficiency, environmental sustainability, and social acceptability. Multiple alternatives, consists of different technologies and resources, must be assessed in multiple objectives. The objective of this study is to develop a multicriteria decision analysis model to select a power generation pathway for Sri Lanka by developing different alternative pathways, examining them across multiple objectives, and incorporating preferences of multiple stakeholders. A pathway; mix of renewable and fossil fuel resources aimed at achieving energy security can meet multiple criteria associated with future power generation.

#### 3 - Calibration of Transportation Models with Scarce Cost Data: A Mathematical Program with Equilibrium Constraints

Charalampos Avraam, Johns Hopkins University, 3400 N. Charles Street, Baltimore, MD, 21218, United States, Anastasia Lambrou, Wei Jiang, Sauleh Ahmad Siddiqui, Anthony So

The lack of detailed cost data in critical sectors of the economic system, such as the Livestock production sector, confines the ability of economic modelers to properly account for critical details, limiting the usefulness to policymakers. In order to calibrate for unknown or uncertain parameters, our proposed calibration method is formulated as a Mathematical Program with Equilibrium Constraints, where the lower level is the market equilibrium problem and the upper level minimizes the difference of the uncertain or unknown parameters from trademark values. Furthermore, we systematize the trade-off between accurately calibrating for a set of parameters versus another.

#### 4 - Solving Problems with Equilibrium Constraints with an Application to Energy Markets

Sauleh Ahmad Siddiqui, Johns Hopkins University, 3400 N. Charles Street, Baltimore, MD, 21218, United States

We provide a new set of optimality conditions for solving mathematical programs with equilibrium constraints and extend them to solve equilibrium problems with equilibrium constraints. We develop algorithms based on nonlinear programming to provide insights into energy markets with hierarchical structures. We conclude with policy insights and recommendations on how this approach can be extended.

## ■ SB47

North Bldg 229A

### Nature-Inspired Heuristics: Overview and Critique

Emerging Topic Session

Chair: Theodore P. Pavlic, Arizona State University, ASU - CIDSE, P.O. Box 878809, Tempe, AZ, 85287-8809, United States

#### 1 - Nature-Inspired Heuristics

Craig Tovey, Nature-Inspired Heuristics, Atlanta, GA, United States

Evolutionary Programming, Genetic Algorithms, Simulated Annealing, Ant Colony Optimization, and Particle Swarm Optimization are among the earliest optimization heuristics inspired by animate and inanimate phenomena in the natural world. Some of the more recently invented methods have exotic names such as Roach Infestation, Shuffled Frog-Leaping, Invasive Weed Optimization, and Cuckoo Search. This tutorial is a guide to the bewildering, burgeoning menagerie of such heuristics, which now comprises more than 100 algorithms, and whose accompanying publications number in the hundreds of thousands. Their underlying principles include populations, recombination, exploration, reinforcement, encoding, selection, randomness and perturbation. They have been successful in many implementations, oftentimes winning out against classical OR/CS methods for implementation or a user's acceptance. They have been less successful, sometimes spectacularly so, in many computational test comparisons with classical methods. I speculate as to why these success levels differ so greatly. On the one hand, I critique the insularity and mathematical naiveté of this heuristic research, particularly its limited nature-versus-nature comparisons and self-contradictory stance on algorithm parameter tuning. On the other hand, I critique the OR community's having implicitly ceded important optimization territory to others, and our failure to face what is now there. In an attempt to spur our community to thoroughly engage with nature-inspired heuristics, I conclude by observing a misalignment between individual and community incentives, identifying a few potentially powerful nature-inspired heuristic ideas for optimization, and proposing some specific research questions that may attract operations researchers.

## ■ SB48

North Bldg 229B

**Modeling the Energy-Water-Land Nexus Across Scales**Sponsored: Energy, Natural Res & the Environment/Energy  
Sponsored Session

Chair: Mohamad Hejazi, PNNL, College Park, MD, 20740, United States

**1 - Energy-Water-Land Nexus: An Integrated Modeling Perspective using GCAM**Mohamad Hejazi, PNNL, 5825 University Research Ct, Ste. 3500,  
College Park, MD, 20740, United States

Energy, water, and land systems are increasingly interconnected. In this study, we use the Global Change Assessment Model (GCAM), where interactions between population, economic growth, energy, land, and water resources interact simultaneously in a dynamically evolving system to explore the role of groundwater resources in meeting future demands for energy, water, and agricultural demands.

**2 - Integrated Assessment of Water-Energy-Land Nexus Solutions for the Indus River Basin**

Simon Parkinson, Austria

The Indus river basin in South Asia is home to an estimated 300-million people. Its freshwaters are critical for human health and regional food and energy security. The Indus faces sustainable development challenges due to rapid population growth, climate change, and extreme water stress hampered by poverty and transboundary disputes. This presentation overviews a new multi-scalar integrated assessment framework that uncovers future pathways balancing basin-wide water, energy and land system interactions and constraints. Preliminary analysis identifies investments supporting infrastructure aligned with development targets. The new framework is readily transferable to other basins.

**3 - Ending Groundwater Overdraft Globally? An Assessment of Water and Food Security Impacts using Integrated Modeling**Tingju Zhu, International Food Policy Research Institute,  
Washington, DC, United States, Karen G. Villholth,  
Edwin Sutanudjaja

Groundwater plays an indispensable role in agricultural production. Yet, aquifers are being depleted in many arid and semi-arid areas. We modified a global water and food simulation model to assess the impacts of ending groundwater overdraft on water supply and food security. It was found that considerable decline in the production of major staple crops can be caused at the global scale, with immediate more severe regional impacts in heavy groundwater-using areas. International prices of significant groundwater-irrigated crop commodities like wheat were found to increase significantly, which potentially increases the population at risk of hunger in the world.

**4 - The Land and Water Implications of Biomass Cofiring in the MISO Region**Jing Liu, Pennsylvania State University, University Park, PA,  
United States, Shanjia Sun, Thomas W. Hertel, Brayam Valqui

Biomass cofiring is a promising and efficient way to provide clean energy for the states that have created Renewable Portfolio Standards. In the MISO region, many power plants are targeting corn residue — the most available and cost effective biomass resource. Should biomass cofiring be widely adopted, the production of corn is expected to expand significantly. This change will have important implications for land and water quality, as corn production intensively uses nitrogen fertilizer and, in some area, water for irrigation as well. The main objective of this study is to explore the potential of biomass cofiring in the MISO region and the associated impacts on land and water resources.

**5 - Modeling the Water-Energy Nexus at the Community Scale: A Case Study of New York City**Mine Isik, United State Environmental Protection Agency,  
Research Triangle Park, NC, United States, Ozge Kaplan

The sustainable supply and efficient use of energy, and the transformation from fossil fuels to renewable energy sources have become strategically important for cities. Regulatory approaches to achieve clean air goals applied on top-down basis tend to yield a significant amount of noncompliance costs. To address this challenge, a community scale, cost optimization linear programming model that focuses on buildings is developed to assess the energy supply systems and the related challenges toward resilient communities while combating climate change are examined in scenario analysis frame.

## ■ SB49

North Bldg 230

**Joint Session ENRE/Practice Curated:Data Analytics and Renewables in Oil & Gas Production**Sponsored: Energy, Natural Res & the Environment/Natural  
Resources Petrochemicals  
Sponsored SessionChair: Sam Aminfard, University of Texas at Austin, Austin, TX,  
United States**1 - Electrifying Oil and Gas Wells With Renewable Energy**  
Sam Aminfard, University of Texas at Austin

Renewable sources such as solar energy can be utilized to power remote electrified well site control systems and to minimize emissions of greenhouse gases. To assess the viability of powering well sites with renewable energy, we first developed a tool to calculate time-varying power loads of electrified well site control systems. We then utilized a transient energy flow model to evaluate the solar power generation and energy storage needed to reliably meet the estimated power loads using on local energy resource availability. Finally, we assessed the feasibility of potential renewable energy and storage options with a life-of-operation economic study.

**2 - Modeling Microgrids at Well Fields**Sam Johnson, University of Texas at Austin, Austin, TX, 78756,  
United States, Jon La Follett

High penetrations of renewable energy generation could increase downward pressure on electricity prices, which in turn could drive cogeneration plants to seek out alternative profit schemes. Likewise, regulations restricting emissions could motivate industrial electricity consumers to explore alternative power generation options. To identify an optimal operation strategy for facilities facing this predicament, a modeling framework was developed and applied to an existing microgrid. The reliability and resilience of on-site renewable energy generation and integrated energy storage were explored.

**3 - Toward a Global Assessment Framework for Oil and Gas Sector GHG Emissions**Adam Brandt, Stanford University, Mohammad S. Masnadi,  
Jeffrey Rutherford

As the threat of global climate change increases, regulatory limits on the oil and gas industry is becoming more stringent, and long-term emissions reductions look increasingly likely. A particular challenge to addressing oil and gas emissions using current regulatory mechanisms (standards or taxes) is that the industry is profoundly global in nature and crude oil products can cross multiple jurisdictions before reaching consumers. Also, emissions data availability in the global oil industry is generally poor, with many of the data required to estimate emissions being considered proprietary or strategic in nature by companies and thus held closely to operators. We describe an effort to address these issues by developing a combined open-source GHG modeling platform that is data-rich and based on engineering fundamentals. We also describe recent efforts to compile global data sources into the first comprehensive picture of global oil sector emissions, with an emphasis on data and analytical challenges.

## ■ SB50

North Bldg 231A

**Joint Session Practice/Practice Curated Editor's Cut #2: Human Trafficking, Crowdsourcing, Retail**Sponsored: Practice Curated Track  
Sponsored SessionChair: Carrie Beam, University of Arkansas, Walnut Creek, CA, 94596,  
United States**1 - Moderator, Editor's Cut Panel #2 (Human Trafficking, Crowdsourcing, Retail)**Renata Alexandra Konrad, Worcester Polytechnic Institute,  
School of Business, 100 Institute Road, Worcester, MA, 01609,  
United States

This panel will cover the Human Trafficking, Crowdsourcing, and Retail issues of Editor's Cut. Come learn more about the case studies, videos, and other journal articles available free, online.

**Panelists**

Renata Alexandra Konrad, Worcester Polytechnic Institute,  
School of Business, 100 Institute Road, Worcester, MA, 01609,  
United States  
Paul R. Messinger, University of Alberta, Faculty of Business, 3-  
20e Faculty Of Business Bldg, Edmonton, AB, T6G 2R6, Canada  
Richard G. McGrath, United States Naval Academy, 572C  
Holloway Rd, Annapolis, MD, 21402, United States  
Eric Johnson, Vanderbilt, Nashville, TN, United States

**SB51**

North Bldg 231B

**Advances in Project Management and Scheduling**

Emerging Topic: Project Management and Scheduling,  
in Memory of Joe Leung,  
Emerging Topic Session

Chair: George Vairaktarakis, Case Western Reserve University,  
Cleveland, OH, 44106-7235, United States

**1 - The Inventory vs. Timeliness Tradeoff in Project Delivery**

Arman Jabbari, University of California-Berkeley, 2012 Del Norte,  
Berkeley, CA, 94707, United States, Phil Kaminsky

We explore the tradeoffs between inventory cost and project completion times in  
a variety of settings, across single and multiple projects.

**2 - Managing Clinical Trials in a Drug Development Project**

Theodore D. Klastorin, University of Washington, ISOM  
Department, Box 353226, Seattle, WA, 98195-3226, United States,  
Kamran Moinsadeh, Hamed Mamani

We consider the case when a series of clinical trials are needed to validate a new  
drug under development. The issue we consider is related to the number of  
patients to enroll in each trial and when these patients should be enrolled. We  
show how this problem is related to flexible resource allocation problems in  
project management and develop a model that analyzes static versus dynamic  
scheduling strategies.

**3 - Information Asymmetry in Budget Allocation: An Analysis of a Truth-inducing Incentive Scheme**

Yun Zhou, 1989, NDSU, Fargo, ND, United States,  
Joseph Szmerekovsky

Truth-inducing incentive schemes are used to motivate project managers to  
provide unbiased project information to the portfolio manager to reduce  
information asymmetry between the portfolio manager and the project managers.  
To improve the scheme, we identify the proper value of penalty coefficients in the  
truth-inducing incentive scheme when information asymmetry is present. We  
first describe the allocation method that achieves budget optimization under  
certain assumptions and identify the proper coefficients while accounting for the  
differing perceptions of both the portfolio manager and the project managers. We  
report a bound on the ratio between the two penalty coefficients in the truth-  
inducing incentive scheme. We conclude that the penalty coefficient for being  
over budget should be reduced when the portfolio budget is tight and the penalty  
coefficients should be equivalent to the organizational opportunity costs when the  
portfolio budget is sufficient.

**4 - A Cutting Plane Approach for the Multi-Machine Precedence-Constrained Scheduling Problem**

George Vairaktarakis, Case Western Reserve University, Dept of OR  
and OM, 10900 Euclid Avenue, Cleveland, OH, 44106-7235,  
United States, Prahalad Venkateshan, Joseph Szmerekovsky

A cutting-plane approach is developed for the problem of optimally scheduling  
jobs with arbitrary precedence constraints on unrelated parallel machines. Our  
model utilizes a number of valid inequalities that cut off fractional linear  
programming solutions. This leads to an increase of the linear programming lower  
bound from 89.3% to 94.6% of the corresponding optimal solution, and a  
substantial reduction in the computational time of an optimal branch-and-bound  
algorithm for this problem. We report optimal solutions for problem instances  
with up to 25 jobs and 5 machines; more than twice the size of problems for  
which optimal solutions have been reported so far.

**5 - Project Resource Leveling Under Uncertainty**

Hongbo Li, Shanghai University, Baoshan District, Shangda Road  
99, Shangchuan Road 995, Shanghai, 200444, China

We investigate project resource leveling with stochastic activity durations as well  
as resource availabilities to minimize the fluctuations in resource usage. To obtain  
effective scheduling policies for the stochastic resource leveling problem, we  
model the problem as a Markov decision process model and propose approximate  
dynamic programming algorithms built upon Metaheuristics. To evaluate our  
algorithms, we conduct extensive computational experiments on benchmark  
instances.

**SB52**

North Bldg 231C

**Joint Session Award/Practice Curated: Social Media Analytics Best Student Paper Competition**

Emerging Topic: Social Media Analytics  
Emerging Topic Session

Chair: Julie Zhang, University of Massachusetts, Lowell, Operations and  
Information Systems, Lowell, MA, United States

**1 - Detecting Influence Campaigns in Social Networks Using the Ising Model**

Nicolas Guenon des Mesnards, Massachusetts Institute of  
Technology, Cambridge, MA, USA, .

We consider the problem of identifying coordinated influence campaigns  
conducted by automated agents or bots in a social network. We study several  
different Twitter datasets which contain such campaigns and find that the bots  
exhibit heterophony - they interact more with humans than with each other. We  
use this observation to develop a probability model for the network structure and  
bot labels based on the Ising model from statistical physics. We present a method  
to find the maximum likelihood assignment of bot labels by solving a minimum  
cut problem. Our algorithm allows for the simultaneous detection of multiple bots  
that are potentially engaging in a coordinated influence campaign, in contrast to  
other methods that identify bots one at a time. We find that our algorithm is able  
to more accurately find bots than existing methods when compared to a human  
labeled ground truth. We also look at the content posted by the bots we identify  
and find that they seem to have a coordinated agenda.

**2 - Detecting Changes in Dynamic Events over Networks**

Shuang Li, Georgia Institute of Technology, Atlanta, GA,  
United States

Large volume of networked streaming event data are becoming increasingly  
available in a wide variety of applications, such as social network analysis,  
Internet traffic monitoring and healthcare analytics. How to promptly detect  
changes in these dynamic systems using these streaming event data? In this  
paper, we propose a novel change-point detection framework for multi-  
dimensional event data over networks and cast the problem into sequential  
hypothesis test. We show that our method can achieve weak signal detection by  
aggregating local statistics over time and networks. Finally, we demonstrate the  
good performance of our algorithm on numerical examples and real-world  
datasets from twitter and Memetracker.

**3 - How do Sales Responses to Various User-generated-content?****A Panel VAR Analysis based on Twitch, YouTube and Steam Data**

Shuang Li, Georgia Institute of Technology, Atlanta, GA,  
United States

Twitch.tv (Amazon owned), having over 15 million daily active users, owning  
over 43 percent of game video content market and ranking 4th in in peak US  
internet traffic, is the biggest live stream platform now. The unique features of  
live stream video platforms include timely broadcasting and interpersonal  
interaction, large scale user base and democratized content genre distribution.  
Given these unique features, Twitch has been more and more popular among  
various marketers across different industries as a new form of marketing channel  
which have timely impacts and high efficiency. Meanwhile, pre-recorded video  
platforms like YouTube is also largely used as an effective marketing channel.  
Thus, it is unclear that which platform as better marketing efficiency.  
Additionally, compared with traditional user-generated-content (UGC) like  
reviews, it is unclear that whether user-generated video contents about a product  
on two platforms are associated with the product's reputation in terms of reviews-  
the traditional form of user generated content. To explore these two concerns, we  
merge a unique dataset including game sales and profile data from the largest  
online game distribution platform- Steam, game related data from YouTube and  
Twitch and conduct a comprehensive Panel VAR analysis. We provide both  
empirical and theoretical implications based on summarized finding patterns and  
illustrate contributions of this study.



#### 4 - Opinion Dynamics with Stubborn Agents

David S. Hunter, Massachusetts Institute of Technology,  
Cambridge, MA, United States

We consider the problem of optimizing the placement of stubborn agents in a social network in order to maximally impact population opinions. We assume individuals in a directed social network each have a latent opinion that evolves over time in response to social media posts by their neighbors. The individuals randomly communicate noisy versions of their latent opinion to their neighbors. Each individual updates his opinion using a time-varying update rule that has him become more stubborn with time and be less affected by new posts. The dynamic update rule is a novel component of our model and reflects realistic behaviors observed in many psychological studies. We show that in the presence of stubborn agents with immutable opinions and under fairly general conditions on the stubbornness rate of the individuals, the opinions converge to an equilibrium determined by a linear system. We give an interesting electrical network interpretation of the equilibrium. We also use this equilibrium to present a simple closed form expression for harmonic influence centrality, which is a function that quantifies how much a node can affect the mean opinion in a network. We develop a discrete optimization formulation for the problem of maximally shifting opinions in a network by targeting nodes with stubborn agents. We show that this is an optimization problem with a monotone and submodular objective, allowing us to utilize a greedy algorithm. Finally, we show that a small number of stubborn agents can non-trivially influence a large population using simulated networks.

### ■ SB53

North Bldg 232A

#### Joint Session AMD/RMP: Machine Learning and Optimization for Automated Mechanism Design

Sponsored: Auction and Marketing Design

Sponsored Session

Chair: Ellen Vitercik, Carnegie Mellon University, Pittsburgh, PA, 15213, United States

#### 1 - Automated Design of High-Revenue Combinatorial Auctions

Tuomas W. Sandholm, Carnegie Mellon University, Gates Center  
for Computer Science, Carnegie Mellon University, Pittsburgh, PA,  
15213, United States, Anton Likhodedov

Designing revenue-maximizing combinatorial auctions is a key problem, unsolved even for two items. Automated mechanism design [Conitzer & Sandholm UAI-02] uses computational techniques to design mechanisms. In this paper [Operations Research 2015; extends our AAAI-04 & 05 papers], we introduced two ideas to (automated) mechanism design: 1) search for a good mechanism in parametric families where all mechanisms in the family satisfy desirable properties (e.g. incentive compatibility), and 2) using samples of valuations as input rather than assuming a prior distribution (which can be doubly exponential, thus unrealistic). This begat deterministic mechanisms with highest known revenues.

#### 2 - Mechanism Design for Correlated Valuations: Efficient Methods for Revenue Maximization

Michael Albert, Duke University, 308 Research Drive, Durham,  
NC, 27708, United States, Peter Stone, Vincent Conitzer,  
Giuseppe Lopomo

In this work, we provide a both computationally and sample efficient method to design mechanisms that can robustly incorporate an imprecise estimate of the distribution over bidder valuations, using samples from the true distribution, in a way that provides strong guarantees that the mechanism will perform at least as well as ex-post mechanisms, while also performing nearly optimally with sufficient information. We also demonstrate through simulation that this new mechanism design paradigm generates mechanisms that perform significantly better than traditional mechanism design techniques.

#### 3 - Optimal Auctions through Deep Learning

Zhe Feng, Harvard University, Cambridge, MA, United States,  
Paul D. Tting, Harikrishna Narasimhan, David C. Parkes

In this work, we initiate the exploration of the use of tools from deep learning for the automated design of optimal auctions. The design objective is revenue optimal, DSIC auctions. We show that multi-layer neural networks can learn almost-optimal auctions for settings for which there are known analytical solutions (including results due to Myerson, Manelli-Vincent, Pavlov, Daskalakis et al., ). Moreover, this can be done without appealing to characterization results. We are also able to design essentially optimal auctions for poorly understood problems, as well as obtain state-of-the-art results for combinatorial settings that have been studied in the framework of automated mechanism design.

#### 4 - A General Theory of Sample Complexity for Multi-item Profit Maximization

Ellen Vitercik, Carnegie Mellon University, Pittsburgh, PA, 15213,  
United States, Maria-Florina Balcan, Tuomas W. Sandholm

The design of profit-maximizing multi-item mechanisms is a notoriously challenging problem. The mechanism designer's goal is to field a mechanism with high expected profit on the distribution over buyers' values. Unfortunately, if the set of mechanisms he optimizes over is complex, a mechanism may have high empirical profit over a small set of samples but low expected profit. How many samples are sufficient to ensure that the empirically optimal mechanism is nearly optimal in expectation? We uncover structure shared by a myriad of auctions that allows us to prove strong sample complexity bounds: for any set of buyers' values, profit is a piecewise linear function of the mechanism's parameters.

### ■ SB54

North Bldg 232B

#### Interactions in Supply Chains

Sponsored: Behavioral Operations Management

Sponsored Session

Chair: Michael Becker-Peth, Rotterdam School of Management,  
Erasmus University, Rotterdam, 3062 PA, Netherlands

#### 1 - Behavioral Biases in Newsvendor Competition: An Indirect Evolutionary Approach

Ilkka Leppanen, Loughborough University, School of Business and  
Economics, Epinal Way, Loughborough, LE11 4NZ,  
United Kingdom

Recent literature has shown that behavioral biases can explain nonnormative decision making of competing newsvendors. We use an indirect evolutionary approach where players maximize biased utility functions but actual profits determine fitness to study 2 behavioral biases, reference effects based on profit comparisons and overconfidence, in newsvendor competition. We show that both kinds of behavioral biases can be evolutionarily stable and lead to increases in inventory levels from the profit-maximizing equilibrium quantities, in line with experimental findings reported in literature.

#### 2 - How to Improve Forecast Performance - Are Two Humans Better than One?

Michael Becker-Peth, Rotterdam School of Management, Erasmus  
University, Burgemeester Oudlaan 50, Rotterdam, 3062 PA,  
Netherlands

We investigate how Marketing and Supply Chain Department interact in sharing forecasting data in a real world setting. We find that when Marketing is in charge of editing the SAP forecast, they inflate substantially. After inserting Supply Chain Department as middle man, the performance increases because SCM anticipates the forecast inflation and reduces the effect.

#### 3 - Strategic Inventories in Dual Channel

Yan Lang, University of Texas at Arlington, 701 S. Nedderman Dr.,  
Arlington, TX, 76019, United States, Kay-Yut Chen

We study the effect of choosing to strategically withhold inventories in a perfect information dual channel environment, which contains one supplier and one retailer. We design a series of laboratory experiments, which subjects are facing different market power and inventory holding cost issues, to test our hypotheses of equilibrium strategies.

#### 4 - An Empirical Analysis of Buyer Strategic Ordering Decisions through a Behavioral Experiment

Minseok Park, Salisbury University, 1101 Camden Ave. Perdue  
Hall 334, Salisbury, MD, 21801, United States, Pelin Pekgun,  
Sriram Venkataraman, Manoj Malhotra

Theoretical literature shows that certain allocation policies can reduce order inflation behavior of buyers, while empirical evidence is scarce. In this study, through behavioral lab experiments, we analyze the impact of a capacity allocation policy and different information disclosures on the buyer ordering decisions in a single-supplier, two-buyer supply chain.

## ■ SB55

North Bldg 232C

### Joint Session Sports/Practice Curated Sports Analytics I

Sponsored: SpORts

Sponsored Session

Chair: Walter DeGrange, CANA Advisors, Chapel Hill, NC, 27517, United States

#### 1 - Sports Analytics: Making a Difference or Just a Way to get Free Tickets

Walter DeGrange, CANA Advisors, 6727 Falconbridge Rd, Chapel Hill, NC, 27517, United States

With the recent success of sports teams heavily using analytics (Astros, Eagles, Penguins, Warriors, Leicester City F.C.), does this mean that analytics has gained a foothold in the sports world? And if so, is there a career path that a high school student can use to become a sports analytics professional? This presentation attempts to answer both of these questions and summarizes all the areas of the application of analytics in sports. It also adds another year of professional team results and additional factors.

#### 2 - NHL Expansion Draft Optimization

Timothy Chan, University of Toronto, Mechanical and Industrial Engineering, 5 Kings College Road, Toronto, ON, M5S 3G8, Canada, Kyle Booth, Yusuf Shalaby

Las Vegas became the 31st team in the National Hockey League in 2017. To build an initial roster, an expansion draft was held where Vegas selected one player from each of the existing teams. Existing teams were allowed to protect a subset of their players from being selected. In this talk, we present integer optimization formulations that model the protection and selection decision problems. We use this optimization framework to investigate how existing teams can reduce Vegas' team value by making roster moves to improve protection of their assets. We also illustrate how this model can provide Vegas with insight on which teams it may have leverage to extract additional assets through the draft.

#### 3 - How to Play Fantasy Sports Strategically (and Win)

Raghav Singal, Columbia University, New York, NY, United States, Martin Haugh

Daily Fantasy Sports (DFS) is a multi-billion dollar industry. We provide a coherent framework for constructing DFS portfolios where we explicitly model the behavior of other DFS players. We maximize the expected reward and connect the problem to the mean-variance optimization from finance literature, allowing us to solve our problem using a sequence of binary quadratic programs. We also introduce a Dirichlet-multinomial process for modeling opponents' behavior, enabling us to predict and embed opponents' actions in our decision-making in addition to estimating the value of "insider trading" and "collusion". We demonstrate the value of our framework by participating in DFS contests.

## ■ SB56

West Bldg 101A

### HAS Pierskalla Best Paper Award – I

Sponsored: Health Applications

Sponsored Session

Chair: Jeremy Goldhaber-Fiebert, Stanford, Stanford, CA, United States

Co-Chair: Sze-chuan Suen, University of Southern California, Los Angeles, CA, 90089-0193, United States

Co-Chair: Margaret L. Brandeau, Stanford University, Stanford, CA, 94305-4026, United States

#### 1 - Bayesian Sequential Learning for Clinical Trials of Multiple Correlated Medical Interventions

Ozge Yapar, University of Pennsylvania, Philadelphia, PA, United States, Stephen Chick, Stephen Chick

We propose an approach to clinical trial design that integrates three important, emerging trends: design for cost-effectiveness, which ensures health-economic improvement of new interventions; multi-arm design, which simultaneously compares multiple interventions; and adaptive design, which dynamically adjusts the sample size and allocation of patients to different interventions over the course of the trial. We construct a multi-arm, adaptive sampling policy to maximize the expected population-level benefit and provide numerical results that illustrate the benefits in the context of trials that test multiple combinations of therapies and Phase II/III dose-finding trials.

#### 2 - Maximizing Intervention Effectiveness

Rongqing Han, University of Southern California, 1111 Wilshire Blvd, Room 406, Los Angeles, CA, 90017, United States, Vishal Gupta, Song-Hee Kim, Hyung Paek

Policymakers often seek to roll-out an intervention previously proven effective in a research study, possibly subject to resource constraints. We propose a robust optimization framework to guide this roll-out to maximize intervention effectiveness. Our method uses the types of evidence typically available in a published study to identify a subset of patients for treatment. We prove performance guarantees on the method and present a case study assessing its benefits using data from a large teaching hospital in the context of reducing emergency department visits through case management.

#### 3 - Interpreting Predictive Models for Human-in-the-Loop Analytics

Hamsa Sridhar Bastani, Wharton School, Wharton School, Philadelphia, PA, United States, Osbert Bastani, Carolyn Kim

Interpretability has become an important issue as machine learning is increasingly used to inform consequential decisions. We propose an approach for interpreting complex "blackbox" models by extracting a decision tree that approximates the model. Our algorithm provably avoids overfitting by actively sampling new training points using the blackbox model. We use this technique to interpret a random forest classifier for predicting diabetes risk. Physicians successfully used our interpretation to discover an unexpected causal issue in the diabetes classifier.

#### 4 - Timing it Right: Balancing Inpatient Congestion versus Readmission Risk at Discharge

Pengyi Shi, Purdue University, 403 W. State St, Krannert School of Management, Kran 472, West Lafayette, IN, 47907, United States, Jonathan Helm, Jivan Romain Deglise-Hawkinson, Julian Pan

When to discharge a patient plays an important role in hospital patient flow management as well as quality of care and patient outcomes. In this work, we develop and implement a practical decision support tool to aid hospitals in managing the delicate balance between individual readmission risk and ward congestion. Our framework integrates a new prediction model that updates the readmission risk over a patient's hospital stay with a large-scale Markov Decision Process (MDP) to optimize state-dependent discharge decisions. We overcome both practical challenges in the prediction and the curse of dimensionality in the MDP. Lastly, we discuss the ongoing implementation efforts of this discharge tool.

#### 5 - Flexible FDA Approval Policies

Taylor Corcoran, University of California-Los Angeles, 110 Westwood Plaza, Los Angeles, CA, 90024, United States, Elise Long, Fernanda Brava

The FDA requires clinical trial evidence that is statistically significant at the 2.5% level when approving novel drugs, but the agency often uses regulatory discretion when interpreting these standards. Factors such as target disease severity, prevalence, and availability of existing therapies are qualitatively considered, yet no quantitative framework is used to evaluate how such characteristics impact approval standards. We propose a novel queueing network model to analyze the drug approval process, which explicitly incorporates these factors, as well as obsolescence among drugs.

## ■ SB57

West Bldg 101B

### Joint Session HAS/Practice Curated: Experiments in Health Care Operations

Sponsored: Health Applications

Sponsored Session

Chair: Hummy Song, Philadelphia, PA, 19104, United States

#### 1 - The Effects of Occupancy Information Hurdles and Physician Admission Decision Noise on Hospital Unit Utilization

Song-Hee Kim, University of Southern California, Los Angeles, CA, United States, Jordan D. Tong, Carol Peden

Hospital units usually have high demand that exceeds their capacity, requiring physicians to make admission decisions. Under reasonable conditions, the optimal admission policy should depend on the arriving patient's severity and the occupancy upon a patient's arrival. In practice, the occupancy is not always readily accessible and there may exist occupancy information hurdles. We recruit physicians and MTurk workers to study how occupancy information hurdles may systematically affect admission decision behavior. We also examine how random error (in the policy selection and policy execution) may drive predictable biases of over- or under-occupied units depending on the system parameters.

## 2 - Priority & Predictability: The Differential Effects of Emergent and Scheduled Hospital Admissions

Jillian Berry Jaeker, Boston University, 595 Commonwealth Avenue, Room 657A, Boston, MA, 02215, United States

Using experimental and patient-level data, this study focuses on the impact of incoming patient admission type (scheduled or emergent) on the probability of admission and LOS, and the moderating effect of high workload. We also provide a counterfactual analysis of the possible savings achieved through higher predictability in demand.

## 3 - Shared Medical Appointments – An Innovative Approach to Healthcare Delivery

Nazli Sonmez, London Business School, Regent's Park, London, NW1SN, United Kingdom, Kamalini Ramdas, Ryan W. Buell

We examine shared medical appointments (SMAs) as a substitute for regular one-on-one appointments. Under this innovative approach, a group of patients with similar chronic conditions meet with a doctor simultaneously. We conduct a randomized controlled trial at the Aravind Eye Hospital's Glaucoma Clinic, in Pondicherry, India to assess the effectiveness of shared medical appointments versus traditional one-on-one appointments for glaucoma. Preliminary results obtained with the data suggest that the knowledge and satisfaction level of patients who attend shared medical appointments is significantly higher than that of patients who attend one-on-one appointments.

## 4 - Optimal Newborn Screening Algorithm for Cystic Fibrosis

Seyedehsaloumeh Sadeghzadeh, Virginia Institute of Technology Blacksburg, VA, 24060, United States, Hussein El Hajj, Ebru Korular Bish, Douglas R. Bish

Cystic fibrosis (CF) is one of the most prevalent genetic disorders in the United States. Newborn screening for CF allows for early diagnosis, and can improve health outcomes, whereas a delayed diagnosis may result in severe symptoms or fatality. All 50 states of the United States perform newborn screening for CF, starting with a bio-marker test, followed by a genetic test for newborns with elevated bio-marker levels. We develop a stochastic optimization model to determine an optimal bio-marker threshold and set of CF mutations to be tested, in order to minimize the expected misclassification cost. Our case study shows that the optimal combination can substantially reduce the misclassification cost.

## ■ SB58

West Bldg 101C

### MSOM

Sponsored: Manufacturing & Service Oper Mgmt

Sponsored Session

Chair: Saravanan Kesavan, University of North Carolina-Chapel Hill, Kenan-Flagler Business School, Cb 3490 Mccoll Building, Chapel Hill, NC, 27599-3490, United States

Co-Chair: Tunay Tunca, University of Maryland, 518 Memorial Way, Graduate School of Business, Stanford, CA, 94305, United States

Co-Chair: Yi Xu, University of Maryland, DO & IT Department, Smith School Of Business, College Park, MD, 20742, United States

## 1 - Flexible FDA Approval Policies

Taylor Corcoran, University of California-Los Angeles, 110 Westwood Plaza, Los Angeles, CA, 90024, United States, Elise Long, Fernanda Brava

The FDA requires clinical trial evidence that is statistically significant at the 2.5% level when approving novel drugs, but the agency often uses regulatory discretion when interpreting these standards. Factors such as target disease severity, prevalence, and availability of existing therapies are qualitatively considered, yet no quantitative framework is used to evaluate how such characteristics impact approval standards. We propose a novel queueing network model to analyze the drug approval process, which explicitly incorporates these factors, as well as obsolescence among drugs.

## 2 - A Re-solving Heuristic with Uniformly Bounded Loss for Network Revenue Management

Pornpawee Bumpensanti, Georgia Institute of Technology, 755 Ferst Drive NW, Atlanta, GA, 30332, United States, He Wang

We consider a network revenue management problem. The goal is to find a customer admission policy that maximizes expected revenue over a fixed finite horizon. We study a class of re-solving heuristics. These heuristics periodically re-solve the deterministic linear program (DLP), where random customer arrivals are replaced by their expectations. We find that frequently re-solving the DLP produces the same order of revenue loss as one would get without re-solving. However, by re-solving the DLP at a few selected time points and applying thresholds to the customer acceptance probabilities, we design a new algorithm that has a revenue loss bounded by a constant that is independent of the horizon length.

## 3 - Frustration-based Promotions: Field Experiments in Ride Sharing

Baek Jung Kim, NYU Stern, 40 West 4th Street, Tisch Hall, New York, NY, 10012, United States, Michael-David Fiszer, Maxime Cohen

In this talk, we examine whether a firm should proactively send compensation to users who have experienced a frustration (i.e., a poor service quality). In collaboration with one of the leading ride-sharing platforms, Via, we designed and ran three field experiments to investigate how different compensation types affect the engagement of riders who experienced a frustration.

## 4 - A Dynamic Clustering Approach to Data-Driven Assortment Personalization

Sajad Modaresi, UNC Chapel Hill, Kenan-Flagler Business School, Chapel Hill, NC, 27514, United States, Fernando Bernstein, Denis Sauré

A retailer faces heterogeneous customers with initially unknown preferences. The retailer can personalize assortment offerings based on available profile information; however, users with different profiles may have similar preferences, suggesting that the retailer can benefit from pooling information. We propose a dynamic clustering policy that adaptively adjusts customer segments and personalizes the assortment offerings. We test the policy's performance using a dataset from a Chilean retailer.

## 5 - Shipping Consolidation Across Two Warehouses with Delivery Deadline and Expedited Options for E-commerce and Omni-channel Retailers

Lai Wei, University of Michigan, Ann Arbor, MI, United States, Stefanus Jasin, Roman Kapuscinski

Shipment consolidation is commonly used to avoid some of the shipping costs. However, when pending current orders are consolidated with future orders it may require more expensive expedited shipment to meet shorter deadlines. In this paper, we study the optimal consolidation policy focusing on the trade-off between economies of scale and expedited shipping cost. The optimal policies and their structures are characterized, where the impact of expedited shipment on both shipping policy and order fulfillment policy are explored. Two easily implementable heuristics are proposed, which perform within 1-2% of the optimal in intensive numerical tests.

## 6 - Inconvenience, Liquidity Constraints and the Adoption of Off-Grid Lighting Solutions

Bhavani Shanker Uppari, INSEAD, 1 Ayer Rajah Avenue, Singapore, 138676, Singapore, Serguei Netessine, Ioana Popescu, Rowan Clarke

One-fifth of humankind living in poverty does not have access to electricity. An off-grid lighting model that is becoming prominent in impoverished countries is rechargeable bulb technology. We examine, both theoretically and empirically, the impact of liquidity constraints and recharge inconvenience on the usage of rechargeable bulbs. Our analysis has implications for both firm-level operational decisions and government-level policy decisions.

## ■ SB59

West Bldg 102A

## Joint Session HAS/Practice Curated: HIV Prevention, Testing, and Treatment

Sponsored: Health Applications

Sponsored Session

Chair: Pooyan Kazemian, Harvard Medical School, Boston, MA, 02114, United States

## 1 - Optimal Scale-up of HIV Treatment Programs in Resource-limited Settings Under Supply Uncertainty

Sameer Mehta, PhD Student, UT Dallas, TX, United States, Sarang Deo, Charles J. Corbett

In this paper, we study the challenge of scaling-up HIV treatment programs faced by clinics in sub-Saharan Africa. The key trade-off underlying this allocation is between the marginal health benefit obtained by initiating an untreated patient on treatment and that obtained by avoiding treatment interruption of a treated patient. We cast the clinic's problem as a stochastic dynamic program and provide a partial characterization of the optimal policy, which consists of dynamic prioritization of patient segments and is characterized by state-dependent thresholds.



## 2 - Treatment Optimization of Using Darunavir Versus Lopinavir in a Resource Limited Setting with an Unknown Price Ceiling

Jennifer Campbell, Clinton Health Access Initiative, P.O. Box 51071 Ridgeway, Lusaka, Zambia, Marta Prescott, Paul Domanico

The analysis quantifies the value of second-line HIV drugs in complex market settings by addressing treatment sequencing, clinical efficiencies, programmatic heterogeneity and nuanced market paradigms in resource limited countries. The model estimates patient outcomes linked to probabilities of transitioning to different HIV treatment and health states in the medium and long term. The model uses country and region-specific data and clinical outcomes from published sources. Costs and impact, including secondary infections, are included. This work is shared with Ministries of Health and helps set treatment policy priorities, clinical trainings, and procurement for second line treatment.

## 3 - The Cost-effectiveness of HIV Pre-exposure Prophylaxis (PrEP) in High-risk Groups in India

Pooyan Kazemian, Harvard Medical School, 100 Cambridge St, 1695, Boston, MA, 02114, United States, Sydney Costantini, A. David Paltiel, Kenneth A. Freedberg

We leveraged a detailed microsimulation model of HIV prevention and treatment to evaluate the cost-effectiveness of HIV pre-exposure prophylaxis (PrEP) and regular HIV testing for two high-risk groups in India: adult men who have sex with men (MSM) and people who inject drugs (PWID). We conducted sensitivity analysis on multiple parameters related to PrEP and assessed different HIV testing frequencies. Results suggest that a PrEP strategy targeted to these high-risk groups can be cost-effective in India.

## 4 - Surveillance and Control in Networked Disease Dynamics with Individual Response

Ceyhan Eksin, Assistant Professor, Texas A&M University, 3131 TAMU, College Station, TX, 77843, United States

Disease spread is a complex system in which the outcome of intervention policies depends on the disease state, network structure and individual behavior. We consider the viewpoint of a policy-maker that aims to minimize the spread of an infectious disease under budget constraints and unknown disease severity. Daily, the policy-maker decides to spend its funds on information collection or on targeted campaigns that change individual behavior. We characterize optimal policies based on the accuracy of the disease estimate and time horizon for simple networks such as a line, star, and ring. Based on these optimal policies, we design an algorithm that approximates the solution in arbitrary networks.

## SB60

West Bldg 102B

### Personalized Medicine

Sponsored: Health Applications

Sponsored Session

Chair: Dimitris Bertsimas, Massachusetts Institute of Technology, Cambridge, MA, 02139, United States

#### 1 - Personalized Stroke Risk Profiles

Agni Orfanoudaki, MIT, 77 Massachusetts Avenue, Cambridge, MA, United States, Dimitris Bertsimas, Emma Chesley

Established stroke risk calculators from the medical literature utilize traditional linear models to estimate the risk of an adverse event. We present a new interpretable model that captures nonlinearity using data from the Framingham Heart Study. Our machine learning model achieves high performance out of sample, 89% AUC, combining phenotypic, hereditary and genomic information from a longitudinal study. The model has been incorporated in a user-friendly, interpretable application for both physicians and patients to inform their decisions in a clinical setting.

#### 2 - Predicting Cervical Spine Injury in Pediatric Trauma Patients

Holly Mika Wiberg, Massachusetts Institute of Technology, Cambridge, MA, United States, Dimitris Bertsimas

Cervical spine injuries (CSI) are a major concern in pediatric trauma patients. Despite its low incidence, the consequences of missed injuries and challenges in evaluating young non-verbal patients have resulted in high reliance on imaging for injury clearance. Imaging, and particularly CT scans, carries its own set of risks including radiation-induced carcinogenesis. In this work, we leverage optimization and machine learning techniques to predict CSI incidence based on clinical exam findings. We propose an interpretable injury clearance protocol that achieves high identification of injured patients while avoiding a significant proportion of unnecessary imaging.

#### 3 - Prediction and Management of Stroke from Text Data

Rebecca Zhang, Massachusetts Institute of Technology, 70 Pacific Street, Room 362B, Cambridge, MA, 02139, United States, Dimitris Bertsimas, Agni Orfanoudaki

Stroke is the leading cause of preventable disability and the fifth leading cause of death worldwide. A personalization approach can greatly improve the effective management of the risk of stroke and additional complications that arise. While methods utilizing structured clinical data have been popular in the last few years,

the massive amounts of unstructured data available in electronic health records are often neglected. In this work, we develop a natural language processing approach to algorithmically classify patients who have ischemic stroke based on radiology reports and visit notes, and discuss models to predict which go on to develop complications including cerebral edema.

#### 4 - Prescriptive Treatments for Children with Vesicoureteral Reflux

Michael Li, Massachusetts Institute of Technology, Cambridge, MA, United States, Hsin-Hsiao Wang, Dimitris Bertsimas

In current medical practice, every child with Vesico-ureteral reflux (VUR) is treated with antibiotics, in hope to buy time for self-correction. If breakthrough infections occur, then the child is recommended for surgery. We aim to predict VUR and then prescribe personalized treatments. We first predict whether a child has VUR using Optimal Classification Trees, then we prescribe surgery and antibiotics using a two-stage Optimal Classification and Prescription Trees. This, tested against different baseline truths, has AUC of 0.8 in predicting VUR, and achieves 25% reduction in use of antibiotics without affecting the recurrent infection rate in patients.

## SB61

West Bldg 102C

### Joint Session HAS/DM/Practice Curated: Predictive Analytics in Clinical Settings

Sponsored: Health Applications

Sponsored Session

Chair: M. Samie Tootooni, Mayo Clinic, Rochester, MN, 55906

#### 1 - Outcome-Driven Personalized Treatment Design for Managing Diabetes

Eva Lee, Georgia Tech, Industrial & Systems Engineering, Ctr for Operations Research in Medicine, Atlanta, GA, 30332-0205, United States

This work is joint with Grady Health Systems and Morehouse School of Medicine. Diabetes affects 422 million people globally, costing over \$825 billion per year. In the United States, about 30.3 million live with the illness. Current diabetes management focuses on close monitoring of a patient's blood glucose level, while the clinician experiments with dosing strategy based on clinical guidelines and his (her) own experience. In this work, we describe a model for designing a personalized treatment plan tailored specifically to the patient's unique dose-effect characteristics. Such a plan is more effective and efficient for both treatment outcome and treatment cost than current trial-and-error approaches. Implementation results will be discussed.

#### 2 - A Machine Learning Based Personalized Intervention Model to Reduce COPD Readmissions

Sujee Lee, University of Wisconsin-Madison, 402 N. Eau Claire Avenue, Unit 302, Madison, WI, 53705-2820, United States, Philip A. Bain, Jo Goffinet, Christine Baker, Jingshan Li

In this talk, we introduce a machine learning based personalized intervention model to reduce COPD readmissions. Specifically, a machine learning predictive model is trained to predict the readmission risk of a COPD patient based on his/her status at discharge. Using this model, the impact of potential intervention policies is analyzed. Then, the predictive model re-evaluates the risk based on updated information during interventions, and new intervention strategies will be adjusted dynamically.

#### 3 - Mapping Free Text Chief Complaints using an Adaptive Natural Language Processing Approach

Mohammad Samie Tootooni, PhD, Mayo Clinic, Rochester, MN, 55906, United States, Mustafa Y. Sir, Kalyan Pasupathy, Heather Heaton, Casey Clements

We provide a comprehensive structured list to categorize the [free-text] chief complaints. We also developed a heuristic algorithm, equipped with an iterative enhancement procedure to map the recorded chief complaints into the structured list. The data includes all chief complaints recorded at the emergency department of Mayo Clinic in Rochester, MN in 2016 and 2017. Using a bi-level validation process a total sensitivity of 94.2% with specificity of 99.8% and F-score of 94.7% are obtained. The result is reported individually for each main syndrome group as well. In conclusion, the proposed mapping tool can help the field's researchers to incorporate the chief complaints into their models.

## ■ SB62

West Bldg 103A

**Data Mining Theoretical Paper Finals**

Sponsored: Data Mining

Sponsored Session

Chair: Tong Wang, University of Iowa, Iowa City, IA, 52245, United States

Chair: Ramin Moghaddass, University of Miami, Miami, FL

Abstract not available.

## ■ SB63

West Bldg 103B

**Joint Session DM/Practice Curated: Data Analytics and Modeling for Health Informatics and Decision Making**

Sponsored: Data Mining

Sponsored Session

Chair: Shouyi Wang, PhD, The University of Texas at Arlington, 500 West First Street, Arlington, TX 76019, Arlington, TX, 76019, United States

**1 - Information Loss from Parameter Estimation in Discrete Distributions with an Application in Genetics**

Maryam Moghimi, PhD Candidate, The University of Texas at Arlington, Arlington, TX, 76019, United States, Herbert W. Corley

We consider the information loss due to the use of a statistic  $T(X)$  to characterize an  $n$ -dimensional vector  $X$  of random variables representing discrete data. In other words, we compare the probability that a random sample  $X$  of size  $n$  takes on the value  $x$  to the probability that  $X$  is  $x$  given the statistic satisfies  $T(X)$  is  $T(x)$ . We focus on sufficient statistics to develop a general formula for the Shannon information loss due to this data reduction. Applications of this approach will be discussed, including an example on gene sequencing.

**2 - A Chronological Pharmacovigilance Network Analysis Approach for Predicting Adverse Drug Events**

Behrooz Davazdahemami, PhD Candidate, Oklahoma State University, Stillwater, OK, 74075, United States, Dursun Delen

In this study, we extend prior research by proposing a chronological network analysis (NA) approach for predicting adverse drug events (ADEs) before the drugs' approval. Combining known drug-ADE associations from the biomedical literature with information about drugs' target proteins for pre-2001 approved drugs, a drug-ADE network was constructed and used as a basis to train machine-learning (ML) models. The models were validated by predicting drug-ADE associations for post-2001 drugs. The promising results (92.9% accuracy, 72.8% sensitivity) achieved by the ensemble ML models shows the incredible power of such models, in combination with NA, for capturing sophisticated drug-ADE patterns.

**3 - Hemodynamic Pattern Discovery and Classification with Children Who Stutter Using Functional Near-infrared Spectroscopy**

Rahil Hosseini

In this paper, we developed a novel supervised sparse feature learning approach to discover discriminative biomarkers from functional near infrared spectroscopy (fNIRS) brain imaging data recorded during a speech production experiment from 46 children in three groups: children who stutter ( $n = 16$ ); children who do not stutter ( $n = 16$ ); and children who recovered from stuttering ( $n = 14$ ). We made an extensive feature analysis of the cerebral hemodynamics from fNIRS signals and selected a small number of important discriminative features using the proposed sparse feature-learning framework. The discovered set cerebral hemodynamics features are presented as a set of promising biomarkers to elucidate the underlying neurophysiology in children who have recovered or persisted in stuttering and to facilitate future data-driven diagnostics in these children.

**4 - A Statistical Network Modeling Approach for Discriminative Brain Network Connectivity Analysis**

Shouyi Wang

There are many studies focusing on network detection in multivariate (MV) time-series data. A great deal of focus have been on estimation of brain networks using fMRI, fNIRS and EEG. We propose a sparse weighted directed network (SWDN) estimation approach which can detect the underlying minimum spanning network with maximum likelihood and estimated weights based on linear Gaussian conditional relationship in the multivariate time series. Considering the brain neuro-imaging signals as the multivariate data, we evaluated the performance of the proposed approach using the publicly available fMRI data-set and the results of the similar study which had evaluated popular network estimation approaches on the simulated fMRI data. Moreover, we applied the proposed network construction method as a feature extraction technique from fMRI data to classify the patterns of the Parkinson Disease.

## ■ SB64

West Bldg 104A

**Joint Session DM/AI/Practice Curated: Unstructured Data Mining: Methods and Applications**

Sponsored: Data Mining

Sponsored Session

Chair: Chaojiang Wu, Drexel University, 3141 Chestnut Street, Philadelphia

**1 - Investor's Opinion Divergence and Stock Return Volatility: Evidence from User-generated Content**

Yang Li, Drexel University LeBow College of Business, PA, United States

This paper examines the relationship between investors' opinion divergence and stock return volatility using daily user-generated content (UGC) data of 66 most discussed stocks from a social media platforms for investors in the U.S. Our research adds to the emerging body of literature on the impact of UGC on the stock market regarding: (1) novel techniques for systematically measuring sentiment divergence in large-scale UGC data; and (2) uncovering the dynamic interdependence of the relationship between investors' opinion divergence and stock volatilities.

**2 - Deep Learning for Predicting Research Topic Trends**

Jiangnan He, Drexel University College of Computing and Informatics, PA, United States

Text data can be useful for predicting topic trends in the future. The prediction can be beneficial for various applications. In this study, we represent the semantic and structural dynamics of research topics by embedding learning and propose a deep learning model that can capture discriminative features for predicting research topic trends (rising or falling trend). We train and test the model by using scientific publications from PubMed. Our experimental results show that both semantic and structural dynamics of a research topic has predictive features for its future trend.

**3 - Breadth, Depth, and Conformity: A Double-Hurdle Model for Review Helpfulness**

Chaojiang Wu, Drexel University, 3141 Chestnut Street, Philadelphia, PA, 19107, United States, Feng Mai, Xiaolin Li

Using multi-attribute attitude model as a framework, we show that the helpfulness of a review not only depends on its internal features, but also hinges on its breadth, depth, and content, in relation to other reviews of the product. We construct two novel measures, content entropy and content deviation, and then propose a double-hurdle model to simultaneously estimate the probability of a review being voted and its helpfulness. We show content entropy positively and content deviation negatively related with the helpfulness of a review. We further illustrate that the content deviation moderates the relationship of the numerical rating deviations and helpfulness.

**4 - Person Name Disambiguation Based on Profession**

Haimonti Dutta, Assistant Professor, University at Buffalo, 325P Jacobs Management Center, Buffalo, NY, 14260, United States

Named Entity Disambiguation (NED) is the task of disambiguating entity mentions in natural language text. In this paper, we present a generative model based on Latent Dirichlet Allocation (LDA) to disambiguate entity mentions occurring in noisy text. Each entity is assumed to have a profession and the representative words are generated from the document in which it is mentioned; words representing a profession are further interpreted for the task of disambiguation. Empirical results presented on a corpus of 14020 historical newspaper articles show that this generative model can obtain reasonable accuracy in the task of person name disambiguation.

## ■ SB65

West Bldg 104B

**Joint Session DM/Practice Curated: Big Data Science**

Sponsored: Data Mining

Sponsored Session

Chair: Hongxia Yin, Minnesota State University, Mankato, Mankato, MN, USA

**1 - A Simple and Efficient Hybrid Genetic Algorithm for Minimum Sum-of-squares Clustering**

Thibaut Vidal, Professor, PUC-Rio, Departamento de Informatica, Rua Marques de Sao Vicente, 225, Rio de Janeiro, 22453-900, Brazil, Daniel Gribel

Minimum sum-of-squares clustering (MSSC) is a widely used clustering model. We introduce an efficient genetic algorithm that uses K-means as a local search in combination with problem-tailored variation operators. The approach is scalable and accurate, outperforming all recent state-of-the-art algorithms for MSSC in terms of solution quality, measured by the depth of local minima. This enhanced accuracy leads to classification results which are significantly closer to the ground truth for overlapping Gaussian-mixture datasets with a large number of features. Improved global optimization methods therefore appear to be essential to better exploit the MSSC model in high dimension.

**2 - On the Behavior of the Expectation-maximization Algorithm for Mixture Models**

Babak Barazandeh, University of Southern California, Los Angeles, CA, 90007, United States, Meisam Razaviyayn

Finite mixture models are among the most popular statistical models that are widely used in different data science disciplines. Despite their broad applicability, inference under these models typically leads to computationally challenging non-convex problems. While the Expectation-Maximization (EM) is the most popular approach for solving these non-convex problems, the behavior of this algorithm is not well understood for general mixture model inference problems. In this work, we study the equally weighted mixture of two single dimensional Laplacian distributions and show that every local optimum of the population maximum likelihood estimation problem is global optimum.

**3 - Fourier Transform Inverse Regression Estimators of the Central Subspaces**

Jiaying Weng, University of Kentucky, Lexington, KY, 40503, United States, Xiangrong Yin

We introduce an optimal inverse regression estimator, Fourier transform inverse regression estimator, by optimizing the quadratic discrepancy function using Fourier transforms. We further develop degenerated and robust Fourier transform inverse regression estimators for computational efficiency and robustness, as well as partial Fourier transform inverse regression estimator for predictors consisting both categorical and continuous variables. For sufficient variable selection, we propose shrinkage and sparse group LASSO Fourier transform inverse regression estimators. Furthermore, marginal or conditional hypothesis tests for predictors or dimensions are considered.

**4 - An Smoothing Newton Method for SVM Type Models in Data Analysis**Hongxia Yin, Minnesota State University, Mankato, Department of Mathematics and Statistics, 273 Wissink Hall, Mankato, MN, 56001, United States  
Hongxia Yin, University of Chinese Academy of Sciences, Beijing, 100190, China

An smoothing Newton method for a few support vector machine (SVM) models in data analysis are given by reformulate their dual problems. We proved the global convergence and local super-linear (or quadratic) convergence of the methods. Numerical tests on problems in UCI illustrate the efficiency and robustness of the algorithm compare to the existing results in literature.

## ■ SB66

West Bldg 105A

**Joint Session AI/Practice Curated: Business Applications of Artificial Intelligence**

Sponsored: Artificial Intelligence

Sponsored Session

Chair: Srikar Velichety, The University of Memphis, Memphis, TN

**1 - Does Image Semantics Impact Demand on Digital Sharing Platforms? An Empirical Study Using Deep Learning**

Vivek Kumar Singh, University of South Florida, Tampa, FL, United States, Utkarsh Shrivastava, Anol Bhattacharjee

The digital sharing platforms such as Airbnb encourage customers to seek cues from textual information and images for making an informed decision. Unlike prior studies that focused on only textual information, we study the impact of semantic scenes (e.g. indoor and outdoor) depicted by the property's images and their position within the listing's webpage on the lodging demand. Our propositions are supported by ideas from theories of signaling and information processing and tested using deep learning and econometric modeling approaches. We found that advances in artificial intelligence can indeed provide insights from images at scale for guiding sellers on the digital platforms.

**2 - Seeing the Forest for the Trees: Generating Instrumental Variables with Random Forest for Bias Correction in Statistical Inferences**

Mochen Yang, University of Minnesota, Carlson School of Management, 321-19th Avenue South, Minneapolis, MN, 55455, United States

The practice of combining machine learning with econometric analysis has become increasingly prevalent in empirical research. In the first stage, machine learning methods are typically used to create new variables (e.g., predict sentiment from textual data), which are then added into second stage econometric models as covariates. Because the predictions from machine learning models are inevitably imperfect, the subsequent econometric estimations suffer from biases due to measurement error in covariates. In this paper, we discuss a novel approach that mitigates biases by leveraging instrumental variables that are generated from an ensemble machine learning model, such as a Random Forest.

**3 - A Graphical Model for Topical Impact Over Time**

Zhiya Zuo, University of Iowa, Iowa City, IA, United States, Kang Zhao

After being published, a document, whether it is a research paper or an online post, can make an impact when readers cite, share, or endorse it. Built on supervised topic models, we propose a graphical model to capture the topical impact over time within a corpus of documents. We conducted experiments on papers published in (i) D-Lib Magazine and (ii) The Library Quarterly from 2007 to 2017. Comparing with ToT, we found that our model produced more robust and interpretable results on topical trends over time and. Enabling better understanding and modeling of topical impact over time, this model can be used for the design of social media platforms, and evaluation of scientific contributions and policies.

**4 - A Modeling Framework for Bike Rebalancing Problem in Bike Sharing System**

Fan Dong, University of Arizona, Tucson, AZ, 85715, United States

Bike sharing systems have been implemented in many major cities to offer a convenient mobility service in which public bicycles are deployed in different stations across the city for shared use. The users can check out a bike from a station nearby, take a short ride, and check in the bike to a station around their destination. As the check in and check out of bikes at different stations are unbalanced during different time periods, the bike imbalance issue constantly occurs. Bike stations tend to be full of bikes or empty because the dynamic and asymmetric spatial and temporal bike usage patterns between stations. To ensure good service quality, bike sharing systems need to make sure all stations have enough available bicycles for check out and empty slots for check in. Therefore, system managers need to make decision in advance to send out trucks to dispatch bikes within different stations to rebalancing the bike stations. There are several key challenges related to the bike rebalancing problem: the determination of stations need to be rebalanced, and the dispatch truck routing optimization. In this paper, we design a general framework for bike sharing systems managers to solve the bike rebalancing problems by following steps. The first step is to design a community detection clustering algorithm to cluster bike stations into different communities based on their bike trip network. The second step is to implement a three layer predicting model to predict the check in and check out of bikes for each station in a future period in order to identify the unbalanced stations in future. The third step is to design rebalancing routing algorithm to rebalancing bike stations within and between communities.



## ■ SB67

West Bldg 105B

**Joint Session ISS/Practice Curated: Digital Innovation, Analytics, and Business Value**

Sponsored: Information Systems

Sponsored Session

Chair: Jessica Pye, Arizona State University

**1 - Using Swarm Optimization Heuristics for Winner Determination in Combinatorial Auctions**Karthik Kannan, Purdue University, 3315 Webster Street,  
West Lafayette, IN, 47906, United States, Abhishek Ray

Combinatorial auctions are increasingly being used to allocate bundles of items among interested bidders. However, as the number of bundles increases, it takes exponentially longer to solve for the winners in the auction. In such situations, regular solvers such as IBM CPLEX or AMPL fail to produce the optimal solution either completely due to computational limitations or in reasonable time. We propose an Ant Colony-based algorithm (TrACA) that produces optimal or near-optimal results within specified time. The best value from TrACA is at least as good as best-in-class heuristics in 100 % of the cases. Additionally, to better understand the why deterministic algorithms fail or take too long for approximating winners in such auctions, we analyze empirical hardness of tested instances and use a standard supervised learning method to build a predictive model of TrACA run-times.

**2 - On the Networks of Executives and Firm Strategic Entry: Evidence from the US Broadband Industry**Tedi Skiti, Temple University, Philadelphia, PA, 19123,  
United States, Paul Pavlou

We examine the role of the social and professional networks of the firm's top executives in the firm's geographic entry to new markets. We define networks as social ties (generated by common education and societal activities) and professional ties (generated by common work experiences). Potential entrant firms may have an information asymmetry about the market conditions which might reduce their entry likelihood. Networks may reduce this information asymmetry providing information about competitors and market demand. We combine and utilize firm-level data on broadband deployment in the United States (US) and board member data about their networks and individual characteristics. We find that professional ties mitigate the competitive effects, making entry significantly more likely. We contribute to the limited literature on the role of the network of executives in a firm's strategic entry (before the firm becomes an actual entrant) and the literature on intraorganizational knowledge transfer as the result of individual executives' ties.

**3 - When Your Problem Becomes My Problem: The Impact of Airline IT Disruptions on On-Time Performance of Competing Airlines**Brad N. Greenwood, University of Minnesota, 4200 32nd St S,  
Arlington, VA, 22206, United States, Jennifer Tae, Min-Seok Pang

We study how firm disruptions affect competitor performance in the presence of shared resources. We propose that the impact of disruption is moderated by the routine complexity of both a disrupted firm and a competitor. Our context is the four large IT outages affecting the U.S. airline industry. Competitor flights which originated from, or were inbound to, a disrupted hub experienced significant changes in on-time performance, depending on the routine complexity of the disrupted airline. Performance deteriorated during the disruption of full-service carriers, but improved during that of a low-cost carrier. We also find that this effect is strongly moderated by competitors' routine complexity.

**4 - Chat More and Contribute Better: An Empirical Study of a Knowledge-based Community**Christopher M. Forman, Cornell University, Dyson School of  
Economics, Warren Hall, Ithaca, NY, 14850, United States,  
Xiaomeng Chen, Michael Kummer

Platform design is important to the success of knowledge-based communities. This paper studies whether a new channel of information exchange can impact the efficiency of users' contributions. To test this hypothesis, we use a policy change implemented on the platform. On 2010 October 15, Stack Overflow launched chat.stackoverflow.com to support real-time communication for users. We leverage the fact that not all users could initiate this communication channel to set up a difference-in-differences (DiD) strategy, that compares the questions of the same users before and after the exogenous change. We find mixed evidence of the efficacy of the chat rooms on improving knowledge-sharing outcomes.

## ■ SB68

West Bldg 105C

**QSR Best Refereed Paper Award**

Sponsored: Quality, Statistics and Reliability

Sponsored Session

Chair: Haitao Liao, Ph.D., University of Arkansas, University of  
Arkansas, Fayetteville, AR, 72703, United StatesCo-Chair: Tirthankar Dasgupta, Ph.D., Rutgers University,  
110 Frelinghuysen Rd, Piscataway, NJ, 08854, United States**1 - Change-Point Detection by Multivariate Adaptive Regression**Weihong Guo, Rutgers, The State University of New Jersey,  
Piscataway, NJ, United States**2 - Minimizing Negative Transfer of Knowledge in Multivariate Gaussian Processes: A Scalable and Regularized Approach**Raed Al Kontar, Garvesh Raskutti, Shiyu Ahou, University of  
Wisconsin, Madison, WI, United States**3 - Optimal Placement of Actuators for Composite Fuselage Shape Control**Jianjun Shi, Georgia Institute of Technology, Atlanta, GA,  
United States, Juan Du, Xiaowei Yue, Jeffrey H. Hunt,**4 - Efficient Gaussian Process Prediction using Design-Based Subsampling**Ying Hung, Rutgers State University of New Jersey, Piscataway, NJ,  
United States, Linglin He

## ■ SB69

West Bldg 106A

**Joint Session QSR/Practice Curated: Data Science and Analytics for Quality and Reliability Assurance**

Sponsored: Quality, Statistics and Reliability

Sponsored Session

Chair: Mingyang Li, Tampa, FL, 33647, United States

Co-Chair: Jianguo Wu, Peking University, Haidian District, Beijing

**1 - Prescribing Age Replacement Policies with Minimal Repair in Anticipation of Non-stationary Unpunctual Implementation**Shadi Sanoubar, University of Pittsburgh, Pittsburgh, PA,  
United States, Kai He, Lisa M. Maillart, Oleg A. Prokopyev

We consider the problem faced by a maintenance planner who must prescribe an age-replacement policy in anticipation of the fact that the party implementing the policy may be unpunctual, to a degree that depends on the replacement age itself. Our analytical and numerical results compare the optimal solution and its performance to those when the unpunctual behavior is assumed to be absent or independent of the prescribed replacement time.

**2 - Optimal Maintenance Management of the Deteriorating Water and Transportation Infrastructures with Interdependencies**Hung Nguyen, University of South Florida, Tampa, FL, 33613,  
United States, Noha Abdel-Mottaleb, Shihab Uddin, Qiong Zhang,  
Qing Lu, He Zhang, Mingyang Li

Due to the co-location and spatial proximity, the deteriorating water infrastructure (WI) and transportation infrastructure (TI) are physically and operationally interdependent/dependent. Most of the existing maintenance works mainly consider WI and TI separately, but neglect the complex interdependency/dependency between WI and TI. We will propose an optimal maintenance decision-making framework by jointly prioritizing and maintaining a large number of co-located WI and TI components (e.g., pipes and roads) at the reduced cost. A case study will demonstrate the cost-effectiveness of the proposed work.

**3 - Degradation Modeling and RUL Prediction Using Wiener Process Subject to Multiple Change Points and Unit Heterogeneity**Yuxin Wen, University of Texas-El Paso, 216 W. California Ave,  
El Paso, TX, 79902, United States, Jianguo Wu, Devashish Das,  
Bill Tseng

Degradation modeling is critical for health condition monitoring and remaining useful life prediction (RUL). In the paper, we propose a multiple change-point Wiener process as a degradation model. To take into account the between-unit heterogeneity, a fully Bayesian approach is developed where all model parameters are assumed random. At the offline stage, an empirical two-stage process is proposed for model estimation, and a cross-validation approach is adopted for model selection. At the online stage, an exact recursive model updating algorithm is developed for online individual model estimation, and an effective Monte Carlo simulation approach is proposed for RUL prediction.

#### 4 - Monitoring of User-generated Reviews via a Sequential Reverse Joint Sentiment-topic Model

Qiao Liang, Tsinghua University, Beijing, China, Kaibo Wang

User-generated reviews can serve as an efficient tool for evaluating the customer-perceived quality of online products and services. This article proposes a joint control chart for monitoring the quantitative evolution of topics and sentiments in online customer reviews. A sequential model is constructed to convert the temporally correlated review documents to topic and sentiment distributions, which are subsequently used to monitor the topics and topic-specific opinions in an ongoing product and service process. Simulation studies on various data scenarios demonstrate the superior performance of the proposed control chart in terms of both shift detection and diagnosis.

#### 5 - Optimal Design of Reliability Demonstration Tests with Risk-adjusted Costs

Suiyao Chen, University of South Florida, 5017 Patricia Court, Tampa, FL, United States, Lu Lu, Qiong Zhang, Mingyang Li

Conventional optimal design of reliability demonstration tests (RDTs) mainly minimizes the testing costs within a RDT, but neglects its impacts on subsequent reliability assurance activities, such as reliability growth and warranty. This work investigates the influence of RDT design on its subsequent reliability activities and further proposes an optimal RDT design strategy by jointly considering cost components at both design and operational phases in a more holistic manner. A comprehensive case study is given to demonstrate the benefits of the proposed work under different cost scenarios and prior elicitation settings.

### ■ SB70

West Bldg 106B

#### Joint Session QSR/DM: Condition-based Maintenance Optimization

Sponsored: Quality, Statistics and Reliability

Sponsored Session

Chair: Anahita Khojandi, University of Tennessee, 521 Tickle Building, 851 Neyland Drive, Knoxville, TN, 37996, United States

Co-Chair: Mahboubeh Madadi, Louisiana Tech University, Ruston, LA, 71272, United States

#### 1 - Understanding Wind Turbine Performance for Better Condition Monitoring

Hoon Hwangbo, Texas A&M University, College Station, TX, 77840, United States, Yu Ding

For wind turbines, a direct monitoring of power output data may not be sufficient for tracing the performance change of wind turbines, due to the strong dependency of power output on wind conditions. As such, we model power output as a function of wind variables and provide an approach to monitor the change of the function via a performance metric defined over the function. Since the functional model, albeit data driven, is developed in a way it follows physical restrictions, it is better representative of wind turbine performance and more suitable for the condition monitoring of wind turbines.

#### 2 - Selective Maintenance of Systems with Multiple Dependent Failure Modes

Cesar Ruiz, University of Arkansas, 4183 Bell Engineering Center, Fayetteville, AR, United States, Edward A. Pohl, Haitao Liao

Selective maintenance may be conducted by choosing a subset of possible actions during the downtime of a system. We propose a selective maintenance optimization framework for complex systems with components that have more than one failure mode. In particular, both non-catastrophic and catastrophic failures are considered. The first occurs when the physical characteristic of a component exceeds a predetermined threshold. On the other hand, the time-to-failure of a catastrophic failure is modeled by a Weibull distribution where the scale parameter depends on the state of the non-catastrophic failure process. A genetic algorithm is utilized to determine the optimal maintenance actions.

#### 3 - Dual-stage Attention-based Recurrent Neural Networks for Prognostics and Smart Maintenance

Jos Carlos Hernández Azucena, PhD Student, University of Arkansas, 800 W. Dickson St., Fayetteville, AR, 72701, United States, Haitao Liao

The present work proposes the use of a Dual-Stage Attention-Based Recurrent Neural Network (DA-RNN) for the estimation of remaining useful life of an individual complex system with multivariate measures. Using the C-MAPSS turbine engine run-to-failure datasets (PHM08 data challenge) as a benchmarking setting, an initial implementation is carried out using Python. The potential of the current algorithm and technical modifications that may arise as research progresses are expected to be of great benefit for the advancement of prognostics and smart maintenance.

#### 4 - Joint Optimization of Resource Allocation and Maintenance Planning for a Multi-Facility Infrastructure System

Yue Shi, Yisha Xiang

Maintenance management is intriguing when considering deteriorating facilities at a system level, which represents more challenges on modeling the interdependencies among facilities. Meanwhile, maintenance policies are usually made by agencies responsible for an entire network, leading to an increasing need to optimally allocate the limited budget. This research develops an integrated resource allocation and maintenance planning for a deteriorating transportation infrastructure system that consists of multiple facilities with complex maintenance effects. The proposed method is illustrated using real-world pavement deterioration data from the state of Florida.

#### 5 - Optimizing Condition-based Maintenance for Systems with Degrading Sensors

Anahita Khojandi, University of Tennessee, 521 Tickle Building, Knoxville, TN, 37996, United States, Mahboubeh Madadi

We consider a degrading system with non-silent failures. System failure is costly and it requires an immediate system replacement. The system status can be partially observed using a series of heterogeneous sensors at a given cost. The sensors are not only noisy, but also are prone to degradation themselves, and hence, the sensor noise level is a function of the sensor status. We develop a POMDP model to determine the optimal condition-based maintenance scheme to minimize the total expected discounted cost over an infinite horizon.

### ■ SB71

West Bldg 106C

#### New Methods and Algorithms in Statistical Learning

Sponsored: Computing

Sponsored Session

Chair: Weijun Xie, Virginia Tech, Blacksburg, VA, 24060, United States

#### 1 - The Computational Operations Research Exchange (CORE) Project for NSF

Yunxiao Deng, University of Southern California, Los Angeles, CA, 90089, United States, Carl Kesselman, Suvrajeet Sen

We will introduce a new platform named Computational Operations Research Exchange (CORE) with several illustrative examples. The CORE platform allows OE (Operations Engineering) researchers to leverage data, models, and software created by an ecosystem of researchers so that they are able to use the exchange to demonstrate that the value of their research results using the cyber-infrastructure developed, maintained, and updated by this platform.

#### 2 - Solving Structured Nonconvex Problems in Statistical Learning

Rahul Mazumder, Massachusetts Institute of Technology, Sloan School of Management, 100 Main Street, Cambridge, MA, 02139, United States

Nonconvex problems arise frequently in machine learning, posing challenges from a computational and statistical viewpoint. Continuous especially convex optimization, has played a key role in our understanding of these problems. However, some other well-grounded techniques in mathematical optimization (for example, mixed integer optimization) have not been explored to their fullest potential. I will demonstrate how such techniques can be used to address problems in structured sparsity. I will outline instances in robust statistics, nonparametric function estimation and low-rank factor analysis where such techniques seem to be promising.

#### 3 - Online Active Set Algorithm for Generalized Solution Paths in Machine Learning

Ammon Washburn, University of Arizona, 2552 N. Geronimo, Tucson, AZ, 85705, United States, Neng Fan, Hao Helen Zhang

Parameter tuning is computationally difficult in machine learning due to cross-validation on a large search space. Solution path algorithms (or online active set in optimization) alleviate this difficulty by analytically solving each successive optimization program from previous optimal solutions. The current theory for general online active set assumes certain constraint qualifications and a strictly convex objective that are not met in general for machine learning problems. We extend the theory of online active set to deal with parametric convex QPs with no constraint qualifications and show a particular implementation with a new model of Support Vector Machines.

#### 4 - The CCP Selector: Best Subset Selection for Sparse Ridge Regression from Chance-Constrained Programming

Weijun Xie, Virginia Tech, Blacksburg, VA, 24060, United States,  
Xinwei Deng

This paper studies sparse ridge regression problem. This paper first derives a novel mixed integer conic (MISOC) reformulation and proves that its continuous relaxation is equivalent to the convex integer formulation proposed by literature. Based upon these two formulations, we study two approximation algorithms-greedy and randomized rounding. We develop efficient implementable procedures for both algorithms and prove that under mild conditions, these two approaches yield near-optimal solutions. We numerically compare these two algorithms with the others proposed from literature and show that greedy approach consistently outperforms the other by correctly identifying more features.

## ■ SB72

West Bldg 211A

### Nicholson Student Paper Competition I

Emerging Topic: Nicholson Student Paper Prize

Emerging Topic Session

Chair: John Hasenbein, University of Texas-Austin, 1 University Station Stop C2200, Department of Mechanical Engineering, Austin, TX, 78712-0292, United States

#### 1 - Learning Optimal Online Advertising Portfolios with Periodic Budgets

Lennart Baardman, MIT, Operations Research Center, 77 Mass Ave, Bldg E40-130, Cambridge, MA, 02139-4307, United States,  
Elaheh Fata, Abhishek Pani, Georgia Perakis

We study a novel multi-armed bandit (MAB) problem with periodic budgets and intermittent feedback on rewards and costs. At the beginning of each time period an agent needs to determine which set of arms to pull to maximize the expected total reward, while maintaining a total cost that is within the budget. As the expected revenues and costs of arms are unknown, the agent has to use each period's budget to both explore the values of arms as well as exploit the most efficient set of arms. This model captures the practical setting where advertisers, in each period, have a periodic advertising budget that is used to bid on a portfolio of targets (e.g., search ads or social ads) to maximize the advertising revenue over that period of time. Over time, the efficiency of the picked targets is revealed and the advertiser revises the portfolio accordingly. This is in contrast to deciding which target to bid on one at a time, which is considered in the budget-limited MAB literature. In this paper, we formulate the MAB problem with periodic budgets, that is a hard to solve problem; therefore, we relax the oracle policy to be able to consider a greedy approximation algorithm for it. We propose an optimistic-robust learning (ORL) algorithm that achieves a bounded total expected regret with respect to this oracle, and show its computational performance.

#### 2 - Sustaining Rainforests and Smallholders by Eliminating Payment-delay in a Commodity Supply Chain – It Takes a Village

Joann de Zegher, Stanford University, Via Ortega 473, Suite 226, Stanford, CA, 94305, United States

Millions of poor smallholder farmers produce global commodities, often through illegal deforestation. Multinational commodity buyers have committed to halt illegal deforestation and improve farmers' livelihoods in their supply chains. We propose a profitable way to do so, motivated by field research in Indonesia's palm oil industry. Currently, farmers suffer from delay in payment by processors, and buyers expensively attempt to avoid sourcing from illegally deforested land by monitoring individual farmers. Instead, we propose that buyers reward all farmers in a village by eliminating payment-delay if no production occurs on illegally-deforested land in the village. Using field data, dynamic programming and game theory, we show how eliminating payment-delay improves productivity and profitability for farmers, processors and buyers, and how village-level incentives best halt illegal deforestation.

#### 3 - Hidden Integrality of SDP Relaxation for Sub-Gaussian Mixture Models

Yingjie Fei, Cornell University, Ithaca, NY, United States,  
Yudong Chen

We consider the problem of estimating the discrete clustering structures under Sub-Gaussian Mixture Models. Our main results establish a hidden integrality property of a semidefinite programming (SDP) relaxation for this problem: while the optimal solutions to the SDP are not integer-valued in general, their estimation error can be upper bounded in terms of the error of an idealized integer program. The error of the integer program, and hence that of the SDP, are further shown to decay exponentially in the signal-to-noise ratio. To the best of our knowledge, this is the first exponentially decaying error bound for convex relaxations of mixture models, and our results reveal the "global-to-local

mechanism that drives the performance of the SDP. A corollary of our results shows that in certain regimes the SDP solutions are in fact integral and exact, improving on existing exact recovery results for convex relaxations. More generally, our results establish sufficient conditions for the SDP to correctly recover the cluster memberships of  $(1-\delta)$  fraction of the points for any  $\delta \in (0,1)$ . As a special case, we show that under the  $d$ -dimensional Stochastic Ball Model, SDP achieves non-trivial (sometimes exact) recovery when the center separation is as small as  $\sqrt{1/d}$ , which complements previous exact recovery results that require constant separation.

#### 4- Implementing the Lexicographic Maxmin Bargaining Solution

Anilesh Krishnaswamy, Stanford University, Stanford, CA, 94305, United States, Ashish Goel

There has been much work on exhibiting mechanisms that implement various bargaining solutions, in particular the Kalai-Smorodinsky solution [Moulin, 1984] and the Nash Bargaining solution. Another well-known and axiomatically well-studied solution is the lexicographic maxmin solution. However, there is no mechanism known for its implementation. To fill this gap, we construct a mechanism that implements the lexicographic maxmin solution as the unique subgame perfect equilibrium outcome in the  $n$ -player setting. As is standard in the literature on implementation of bargaining solutions, we use the assumption that any player can grab the entire surplus. Our mechanism consists of a binary game tree, with each node corresponding to a subgame where the players are allowed to choose between two outcomes. We characterize novel combinatorial properties of the lexicographic maxmin solution which are crucial to the design of our mechanism.

## ■ SB73

West Bldg 211B

### JFIG Paper Competition I

Sponsored: Junior Faculty JFIG

Sponsored Session

Chair: Oleg Prokopyev, University of Pittsburgh, 1031 Benedum Hall, Pittsburgh, PA, 15261, United States

Co-Chair: Fatma Kilinc Karzan, Carnegie Mellon University, Pittsburgh, PA, 15217, United States

#### 1- JFIG Paper Competition

Oleg Prokopyev, University of Pittsburgh, Pittsburgh, PA, United States

The 2018 JFIG paper competition features paper submissions from a diverse array of talented junior faculty members. The prize committee evaluated submissions based on the importance of the topic, appropriateness of the approach, and significance of the contribution. After careful review, the prize committee selected a group of finalists to present their research in one of the two JFIG sessions. For information on the finalists and their papers, please refer to the online program..

## ■ SB74

West Bldg 212A

### MCDM Junior Researcher Best Paper Award Finalists

Sponsored: Multiple Criteria Decision Making

Sponsored Session

Chair: Margaret M. Wiecek, Clemson University, Clemson, SC, 29634-1907, United States

#### 1 - From Stakeholder Analysis to Cognitive Mapping and Multi-Attribute Value Theory: An Integrated Approach for Policy Support

Valentina Ferretti, London School of Economics and Political Science, Houghton Street | London | WC2A 2AE, London, United Kingdom

This study proposes and tests a decision support process that integrates three different tools to structure and solve complex decision problems. First, stakeholders' analysis is deployed to identify the key perspectives involved in the decision process. Second, cognitive mapping is used to facilitate participation of the key stakeholders and define a shared set of objectives for the analysis. Finally, Multi Criteria Analysis is employed to identify the best performing alternative among a set of competing projects. Synergies among the three tools and the operability of the proposed framework are discussed.



## 2 - Application of a Novel PROMETHEE-based Method for Construction of a Group Compromise Ranking to Prioritization of Green Suppliers in Food Supply Chain

Milosz Kadzinski, Poznan University of Technology, Piotrowo 2, Poznan, 60-965, Poland

We propose a hybrid outranking-based approach for group decision aiding. It combines novel procedures based on Binary Linear Programming for constructing a compromise ranking with robustness analysis accounting for the decision makers' incomplete preferences. The framework's applicability is endorsed with a study concerning a food processing industry situated in India. The case company has been supported in selecting the most preferred supplier, while considering economic and green criteria and procuring the environmental friendly policy. The study's significance derives from a prodigious focus of the food sector, which is constantly gaining in importance in today's global economy.

## 3 - Bilevel Programming for Generating Discrete Representations in Multiobjective Optimization

Gokhan Kirlik, University of Maryland Medical System, 920 Elkridge Landing Rd, Linthicum Heights, MD, 21090, United States, Serpil Sayin

A bilevel programming formulation is proposed to identify a Decision Maker(DM)'s most preferred solution without generating the entire nondominated set. The bilevel program is capable of delivering an efficient solution that maps into a given set, provided that one exists. If the DM's preferences are known a priori, they can be used to specify the given set. Alternatively, we propose a search method using the bilevel program to obtain a representation of the nondominated set when DM's preferences are not available. The method searches the outcome space using a partitioning scheme. We show that the method finds a representation with a specified coverage error level in a finite number of iterations.

## SB75

West Bldg 212B

## Joint Session MAS/Practice Curated: Cybersecurity Analytics and Applications II

Joint Session

Chair: Natalie M. Scala, Towson University, Dept. of e-Business and Technology Management

### 1 - A Risk Model for Voting Systems at Local Precincts

Natalie M. Scala, Towson University, Dept. of e-Business and Technology Management, 8000 York Road, Towson, MD, 21252, United States, Paul L. Goethals

Cyber, physical, and insider vulnerabilities are threats to the integrity of elections. Most research has predominantly examined cyber threats at the aggregate state level in U.S. elections. Little attention has been paid to insider or human threats, particularly at polling places. This research examines vulnerabilities at polling precincts and develops a risk model, based on Markov chains, to assess total threat. We then identify best practices to mitigate threat and illustrate the application of the model through a case study of a mid-Atlantic state.

### 2 - Cybersecurity Applications of Blockchain Technology

James Howard, Lead Data Scientist and Service Manager, The Johns Hopkins University, 11100 Johns Hopkins Road, Laurel, MD, 20723, United States

Many are lured to blockchain by the promise of security and privacy in the transaction. However, blockchain security and privacy are mostly a myth. But many applications will still benefit from blockchain technology when reliability and trust are at stake. Cybersecurity is a realm rich with applications as an industry founded on reliability and trust for protecting infrastructure, physical and virtual. This talk will look at the cybersecurity industry and how it can use blockchain to provide better service to clients, public and private.

### 3 - Defending Against Chained Cyber-attacks by Adversarial Agents: An Optimization Approach

Vivin Paliath, Arizona State University, Tempe, AZ, 85281, United States, Paulo Shakarian

Cyber-adversaries employ a variety of malware and exploits to attack computer systems. Existing paradigms that model such cyber-adversarial behavior do not account for sequential or "chaining of attacks. We take the first steps toward addressing this need thru a framework that allows for the modeling of sequential cyber-attacks, taking into account complex interdependencies between vulnerabilities and exploits. The framework identifies the overall set of capabilities gained by an attacker through the convergence of a fixed-point operator. We study the problem of determining an optimal defense strategy to block the attacker from gaining certain capabilities.

## SB76

West Bldg 212C

## Modelling and Control of Production Systems

General Session

Chair: Baris Tan, Koc University, Istanbul, 34450, Turkey

### 1 - Integrated Quality and Production Logistics Analysis of Manufacturing Systems with Lead-time Dependent Product Rework Loops

Marcello Colledani, Poltecnico di Milano, Milano, Italy, Alessio Angius

Products whose quality deteriorates with the time spent within specific portions of a manufacturing system are commonly found in the food, semiconductor, and polymer processing industries. Usually, in these systems, perishable parts must be scrapped if their system sojourn time exceeds a certain threshold. However, there are cases, for example in semiconductor wafer front-end production lines, in which these products can be re-inserted in the system and re-processed to meet the lead-time requirements. This paper presents an analytical method for the exact analysis of the lead-time distribution in these systems, providing the capability to support their design and operation.

### 2 - Dynamic Pricing and Lead Time Quotation in a Make-to-Stock Queue

Baris Balcioglu, Sabanci University, Faculty of Engineering and Applied Sciences, Orhanli Tuzla, Istanbul, 34956, Turkey

We study an environment where customers pay more if their demand is instantaneously satisfied. With dynamic pricing and lead-time quotation policies, the manufacturer aims at preventing loss of demand from those who have to wait. As an extension, customers can form two classes: those who are willing to pay more for instantaneous delivery and those who can opt to wait in return for being charged lower prices. We extend the application of the multilevel inventory rationing policy for the manufacturer to serve these different types of customer classes. Via numerical examples, we assess if elaborate dynamic pricing and lead-time quotation policies increase profit when compared to simpler policies.

### 3 - Data-Driven Control of a Production/Inventory System by Using Marking-Dependent Threshold Policy

Baris Tan, Koc University, Rumeli Feneri Yolu, Sariyer, Istanbul, 34450, Turkey, Siamak Khayyati

We introduce the Marked Markov Arrival Process (MMAP) framework to model a production system that generates different signals (markings) based on the system status. We propose a marking-dependent threshold policy to control the system with partial information. We propose a matrix analytical approach to analyze a production/inventory system with MMAP information and demand arrivals and production times that follow a Markov Arrival Process. We then use a joint simulation and optimization approach to determine the parameters of the threshold policy by using the shop-floor data, the processing time data of the machine and its statistical information, and the inventory position.

### 4 - Continuous Simulation Optimization with Model Mismatch

Giulia Pedrielli, Arizona State University, AZ, United States, Alireza Inanlouganji, Georgios Fainekos, Sebastian Pokutta

Multi-fidelity simulation optimization uses low-cost simulation models to optimize functions that can be only evaluated through an expensive, black-box oracle. Current methods are either applicable to discrete problems or suffer from the curse of dimensionality. We propose a novel multi-fidelity continuous global optimization algorithm that works with general low fidelity models, and we use the state of the art Efficient Global Optimization algorithm as a benchmark. Results show that the proposed algorithm can achieve two orders improved accuracy in optimal location identification.

### 5 - Sales and Operations Planning for Product Rollovers Under Limited Capacity

Justus Arne Schwarz, University of Mannheim, Schloss Schneckenhof Ost, Mannheim, 68131, Germany, Baris Tan

A product rollover takes place if a product generation is replaced by its successor. The key decisions are the offered amount of each product generation and their pricing. If the production of the old generation is stopped prior to its withdrawal from the market, an inventory decision has to be made additionally. In contrast to the existing literature, we consider finite production capacities. We propose a stylized model that captures the firm's decisions and the substitution behavior of the customers. Structural insights with respect to the impact of limited production capacity based on analytical solutions and a numerical study are discussed. Extensions to a stochastic setting are outlined.

## ■ SB77

West Bldg 213A

**Data Driven Insights for Decision Making**

Sponsored: Public Sector OR

Sponsored Session

Chair: Tina Rezvanian, Northeastern University, Boston, MA, 02115-4420, United States

Co-Chair: Ergun Ozlem, Northeastern University, Boston, MA

**1 - The Foodome: Systematic Longitudinal Evaluation of Dietary Factors Associated with Coronary Heart Disease**

Soodabeh Milanlouei, Northeastern University, Boston, MA, 02130, United States

Coronary Heart Disease is mainly driven by environmental factors among which diet is a key player. Nutritional epidemiology aims to explain the effect of nutrients on the heart by focusing on one nutrient at a time. Limited to a panel of 150 nutrients, epidemiologists are unable to address the role of a wide range of smaller molecules that we consume through diet. We propose a new methodology called Chemical-Wide Association Study (CWAS), which systematically evaluates multiple chemical factors simultaneously in relation to diseases in an agnostic fashion. We show that CWAS is not only capable of reproducing prior knowledge on diet-disease associations but also detecting new associations.

**2 - Demand Forecast of Emergency Response Operations at United Nations High Commissioner for Refugees**

Tina Rezvanian, Northeastern University, Boston, MA, 02115-4420, United States

United Nations High Commissioner for Refugees runs Emergency Response supply chain for unprecedented demand by 65.6 million forcibly displaced people worldwide. Efficient utilization of available funds significantly depends on accurate regional demand estimations. Although complex models incorporate higher degrees of data characteristics, we find that models in humanitarian logistics need to capture the right balance between flexibility and practicality. This paper aims for optimizing the use of techniques and providing a framework that promotes practicality of advanced analytics

**3 - Donations for the Refugee Crisis: Cash Versus In-kind Assistance**

Telesilla Oly Kotsi, PhD Candidate, Indiana University, Bloomington, IN, United States, Owen Wu, Alfonso J. Pedraza-Martinez

Our study is motivated by fieldwork during the response to the Syrian refugee crisis in north-western Greece. We analyze tradeoffs regarding the mix of assistance (cash and in-kind assistance) that a humanitarian organization should offer to refugee populations. We model a humanitarian organization that aims to maximize its benefit to refugees, local retailers, and local residents. We determine the impact that cash assistance has on all above actors. We find that the introduction of cash assistance increases the importance of the allocation decision of the remaining budget of the humanitarian organization among the goods provided as in-kind assistance to refugees.

**4 - Improving Financial Loan Access for Farmers in Uganda**

Erica Gralla, Assistant Professor, George Washington University, Washington, DC, United States, Jillian Miles

Ugandan farmers struggle to access financial loans. We aimed to understand the dynamics driving this problem and identify the most effective interventions to increase access to loans. A system dynamics model was developed to integrate data from diverse sources. The results highlight some of the most significant barriers to loan access — interest rates and geographic access to financial institutions — and identify combinations of interventions that can lead to broader loan access.

## ■ SB78

West Bldg 213B

**Location and Logistics**

Sponsored: Location Analysis

Sponsored Session

Chair: Sibel Alumur Alev, University of Waterloo, Waterloo, ON, N2L 3G1, Canada

**1 - Locating Law-enforcement Facilities to Intercept Evading Vehicle Flows**

Okan Arslan, HEC Montreal, 5308 Ave Decelles, Montreal, QC, H3T1V8, Canada, Ola Jabali, Gilbert Laporte

We consider locating law enforcement facilities in a transportation network to intercept unlawful vehicle flows traveling between origin-destination pairs, who in turn deviate from their routes to avoid any encounter with such facilities. Vehicle deviations are bounded by a given tolerance. We use duality theory and

polyhedral analysis to reformulate a bilevel model as a single stage equivalent with facet defining inequalities. Results show that locating a station can counterintuitively decrease system effectiveness. We find that, even in the worst scenario, optimally locating stations can dramatically increase system performance and provide significant gains.

**2 - Benders Decomposition for Profit Maximizing Hub Location Problems with Capacity Allocation**

Sibel Alumur Alev, University of Waterloo, 200 University Avenue West, Waterloo, ON, N2L 3G1, Canada, Gita Taherkhani, Seyed Mojtaba Hosseini

We model capacity allocation decisions within profit maximizing hub location problems to satisfy demand of commodities from different market segments. We present a deterministic formulation of this problem and further extend this model considering stochastic demands. We describe two exact algorithms based on a Benders reformulation to solve large-size instances of the problem. Stochastic problem is solved using sample average approximation. Computational results show that large-scale instances can be solved to optimality, and that the proposed Benders decomposition algorithms generate cuts that outperform the best known cuts.

**3 - GIS and the Subtle Proliferation of Optimization**

Alan Murray, University of California at Santa Barbara, Department of Geography, Santa Barbara, CA, 93106, United States

This paper discusses optimization and its formalization to support geographic analysis, planning, management and understanding. It is highlighted that GIS often represent a starting (or ending) point for undertaking optimization through location analytics capabilities. This paper provides an overview of representative models that can be found, highlighting both strengths and weaknesses, including issues of critical evaluation in observed performance and behavior of associated spatial optimization approaches in practice.

**4 - Weber: "Should We Forget About Him in Location Science?"**

Richard Church, University of California, Santa Barbara, 1832 Ellison Hall, UCSB, Santa Barbara, CA, 93106-4060, United States

Many now recognize that Launhardt's location triangle has eclipsed that of Weber's. Perreur (1998) actually asked the question in his paper: "should Weber be forgotten"? In this paper, I will demonstrate that Weber actually proposed a family of location problems that has yet to be tackled.

**5 - Integrated Location and Inventory Modeling for Service Systems: Condition-based Replacements with IoT-based Data**

Erhan Kutanoglu, University of Texas-Austin, OR/IE Graduate Program, Dept of Mechanical Engineering, Austin, TX, 78712, United States, Murat Karatas

We analyze a joint location and inventory problem in service parts logistics taking advantage of data on equipment condition via Internet of Things (IoT) technology. Instead of using a traditional replace-upon-failure policy, our model uses a condition-based part replacement (CBR) policy, finding the optimum condition to replace the parts, while designing the network and allocating the base stock levels. Even though CBR generates more frequent demands which put pressure on inventory, we capture the ideal balance between facility, transportation, inventory, and downtime costs, overall leading to significant cost savings in our preliminary results.

**Sunday, 1:30PM - 3:00PM**

## ■ SC01

North Bldg 121A

**Joint Session OPT/Practice Curated: Applications of Stochastic Mixed Integer Programming**

Sponsored: Optimization/Optimization Under Uncertainty

Sponsored Session

Chair: Haoxiang Yang, Northwestern University, Evanston, IL, 60208, United States

**1 - Optimizing Crashing Decisions in a Project Management Problem with Disruptions**

Haoxiang Yang, Northwestern University, 2145 Sheridan Road, Room C151, Evanston, IL, 60208, United States, David Morton

We introduce a general type of sequential decision problem under uncertainty, where the uncertainty consists of a small number of disruptions, both the magnitude and the timing of which can be random. We consider a special case: a project crashing problem under a single disruption. When a disruption occurs, the duration of an activity which has not started could change. The magnitude of the activity duration change and the timing of the disruption can be random. We formulate a stochastic mixed integer programming (SMIP) model with second stage a mixed integer program. We propose a learning-based branch-and-bound algorithm and evaluate the computational performance of our approach.

## 2 - Optimizing Water Network Mitigation Shortage and Distribution Costs Under Node Damage and Demand Uncertainty

Jiangyue Gong, Texas A&M University, College Station, TX, 77840-7140, United States, Lewis Ntamo, Mark Alan Lawley

Planning for water distribution in a network under unforeseen node damage due to natural hazards and demand uncertainty is challenging. We present a two-stage stochastic programming model for minimizing weighted water shortage and water distribution cost. The model identifies sectors to pressurize in the first stage and determines the assignment of unpressurized sectors to pressurized sectors for water delivery to satisfy demand in the second stage when the uncertainty is resolved.

## 3 - Modeling Wildfire Extended Attack Planning using Stochastic Programming

Brittany Segundo, TAMU, 924 Sun Meadows Street, College Station, TX, 77845, United States, Lewis Ntamo

Wildfires that are not contained after an initial response, called escaped fires, challenge decision-makers due to the high degree of temporal and spatial uncertainty surrounding fire behavior and response. We model the extended attack as a stochastic process and employ probabilistic constraints to limit response to scenarios that are feasible given resource and budgetary constraints. We present an accompanying algorithm that identifies optimal solutions while remaining computationally tractable. These solutions will inform when and how to stage and deploy resources to each fire.

## 4 - Data-Driven Generator Maintenance and Operations Scheduling under Endogenous Uncertainty

Beste Basciftci, Georgia Institute of Technology, H. Milton Stewart School, 755 Ferst Drive NW, Atlanta, GA, 30332, United States, Shabbir Ahmed, Nagi Gebraeel

In this study, our aim is to effectively model and solve the integrated condition-based maintenance and operations scheduling problem of a fleet of generators. We develop a data-driven optimization framework that explicitly considers the effect of the operations decisions on the generators' degradation levels. Since this problem involves decision-dependent uncertainties, we propose a stochastic formulation that captures the resulting endogeneity. Finally, we present computational experiments demonstrating the significant cost savings and computational benefits of the proposed approach.

## ■ SC02

North Bldg 121B

## Joint Session OPT/Practice Curated: Optimization under Uncertainty: Military and Cybersecurity Applications

Sponsored: Optimization/Optimization Under Uncertainty  
Sponsored Session

Chair: Rajesh Ganesan, George Mason University, Fairfax, VA, 22030, United States

## 1 - Critical Node Analysis and System Identification using a Discrete, General Framework for Dependency Mapping

Les Servi, The MITRE Corporation, M/S M230, 202 Burlington Road, Bedford, MA, 01730-1420, United States, Erica Mason, Damon Frezza

A new mission dependency mapping framework is introduced which models the relationship between an overall mission capability and its dependent component's capability. A new genetic algorithm is presented which identifies the framework's parameters using simulated experiments instead of the time-intensive manual alternative. A second new algorithm is presented that uses these parameters to identify the dependent components that have the greatest impact on the mission outcome. Empirical performance is reported both algorithms.

## 2 - Resource-enabled Pathfinding with Mandatory Waypoints and Turn Constraints

Doug Altner, MITRE Corporation, 7515 Colshire Drive, M/S H617, McLean, VA, 22102, United States

This presentation introduces a shortest path problem/robot motion planning problem around obstacles in a continuous space in which 1) new paths through obstacles could be created using a limited number of resources and 2) the path must also come within range of a pre-specified sequence of waypoints and satisfy turn constraints. We develop an A\*-based heuristic for this problem that incorporates elements from constrained shortest path routing, theta\* search, and tour routing. Computational results on over 100 test cases demonstrate our heuristic is a viable solution for this complex problem.

## 3 - An Approximate Dynamic Programming Approach for the Financial Execution of Department of Defense Weapon System Acquisition Programs

Erich D. Morman, Naval Postgraduate School, 298 Watson Street, Apartment A, Monterey, CA, 93940, United States, Rajesh Ganesan, Karla L. Hoffman

Operating in a "use or lose" fiscal environment, weapon system programs return millions-of-dollars each year of unspent funding. These dollars are opportunity costs to program offices representing forgone projects. The inefficiency is due to the institutional use of an inadequate myopic cash allocation policy. Using Q-learning and value function learning, we develop approximate dynamic programming (ADP) approaches to create alternative cash allocation policies. When compared to the myopic policy, our ADP models reveal that between 2% and 7% of funding is at risk of yearly "sweep-up". The research can help program offices interested in improving overall utilization of their annual budget.

## 4 - Dynamic Optimization of the Level of Operational Effectiveness of a Cybersecurity Operations Center under Adverse Conditions

Rajesh Ganesan, George Mason University, 4400 University Drive, Engineering Building MSN 4A6, Fairfax, VA, 22030, United States, Ankit Shah

The analysts at a cybersecurity operations center (CSOC) analyze alerts generated by intrusion detection systems. There are many disruptive factors that affect the alert analysis process and as a result, adversely impact the Level of Operational Effectiveness (LOE) of the CSOC. To improve the LOE, additional resources must be called upon to assist with the alert analysis process. In a resource constrained environment, determining when and how many resources to call upon is non-trivial. In this talk, a reinforcement learning (RL) model for optimizing the LOE of a CSOC is presented. Results indicate that the RL model helps in making better decisions compared to ad-hoc practices employed at the CSOCs.

## ■ SC03

North Bldg 121C

## Managing Innovation

Sponsored: Technology, Innovation Management & Entrepreneurship

Sponsored Session

Chair: Morvarid Rahmani, Georgia Institute of Technology, Atlanta, GA, 30308-1149, United States

## 1 - Delegated Search Impact on Startup Supply Chain Contracting and Order Allocations

Berke Emre Guzelsu, Boston University, 595 Commonwealth Avenue, Boston, MA, 02215, United States, Nitin Joglekar, Pnina Feldman

We examine the effects of a delegated search on startup supply chain contracting. An entrepreneurial startup partners with a collaborative supplier where the supplier needs to iterate on the product to improve the potential size of the market. At the same time, a large potential supplier may poach business from the collaborative supplier by offering a cheaper product if the order allocation it receives from the entrepreneurial startup is sufficiently large. Given these tradeoffs, we evaluate the order allocation decision an entrepreneurial firm can make to influence the collaborative supplier to invest in experimentation and examine alternative contracts to align incentives.

## 2 - Dynamic Innovation Contests and Information Design

Sina Moghadas Khorasani, University of Utah, Salt Lake City, UT, United States, Luis Rayo, George Georgiadis

We solve for the optimal design of innovation contests with multiple stages of success and an exogenous deadline. The principal selects both the award structure of the contest and its information design.

## 3 - Connecting Restaurants: An Exploratory Study of Customer-based Restaurant Networks

Manuel Emilio Sosa, INSEAD, 1 Ayer Rajah Avenue, Singapore, 138676, Singapore, Victor Martinez-Albeniz, Clara Carrera

Online customer reviews play an increasingly important role in service industries. In restaurants, links created by reviewers who visit several restaurants form a network of unobserved connections which may determine restaurants' fate. We empirically investigate the factors that lead to the choice of visiting a restaurant, the mark given to it, and how the position of a given restaurant in the customer-based restaurant networks influences its survival.

## 4 - Operations in Space: Exploring a New Industry

Joel Wooten, University of South Carolina, 1014 Greene St., Columbia, SC, 29208, United States, Christopher S. Tang

Private, commercial spaceflight is changing the course of space exploration. We often think of innovation in terms of products, services, and (more recently) business models. The new space market presents innovation challenges in all of these areas; our paper analyzes the opportunities for novel contributions from the operations management community.



**5 - A Model of Learning and Doing in Innovation Contests**

Sanjiv Erat, University of California-San Diego, Rady School of Mgmt., Otterson Hall, 9500 Gilman Drive MC 0553, La Jolla, CA, 92093-0553, United States, Lakshminarayana Nittala

In the setting of an innovation contest, we conceptualize solvers who exert effort on two orthogonal dimension - (i) effort geared toward “exploration and learning more about the solution space, and (ii) effort geared toward “exploitation of the newly created knowledge and delivering a tangible and usable solution. Using this richer multidimensional conceptualization of “learning and doing in innovation contests, this talk shall discuss the levers available at the contest organizer firm to influence outcomes, and how the focal firm can optimally manage contests.

**SC04**

North Bldg 122A

**Joint Session Integer Programming/OR Frontiers: Machine Learning and Discrete Optimization II**

Sponsored: Optimization/Integer and Discrete Optimization

Sponsored Session

Chair: Thiago Serra, Carnegie Mellon University, Pittsburgh, PA, 15206, United States

**1 - Mathematics of Neural Networks**

Anirbit Mukherjee

In this talk I will give a brief overview of some of the mathematical questions about neural networks that me and Amitabh Basu (with other collaborators) have been exploring. We will start with the results in our ICLR 2018 paper about neurally representable functions (<https://eccc.weizmann.ac.il/report/2017/098/>). We will particularly focus on our recent works (1) (<https://eccc.weizmann.ac.il/report/2017/190/>) proving lower bounds on the size of neural circuits representing certain Boolean functions and (2) our results in the paper in ISIT 2018 (also NIPS 2017 workshop) trying to formalize the connection between autoencoders and sparse coding (<https://arxiv.org/abs/1708.03735>).

**2 - Combinatorial Attacks Against Binarized Neural Networks**

Elias B. Khalil, Georgia Tech, Atlanta, GA, 30318, United States, Amrita Gupta, Bistra Dilkina

Binarized Neural Networks (BNNs) with weights in  $\{-1, 1\}$  and the sign function non-linearity have recently attracted attention due to their small computational overhead. Concurrently, it has been shown that neural nets may be overly sensitive to tiny adversarial changes in the input, which may be detrimental to their use in safety-critical domains. The non-differentiable nature of BNNs poses a challenge to gradient-based robust training methods. We show how to attack a trained BNN, a task that is crucial to robust learning, by solving a Mixed Integer Program, or with a structured decomposition approach. Our attacks are substantially more effective than standard gradient-based attacks on MNIST.

**3 - A Temporal Architecture for Branch and Bound**

Giulia Zarpellon, Polytechnique Montréal, Montréal, QC, Canada, Jason Jo, Andrea Lodi, Yoshua Bengio

The heuristic character of the Branch and Bound (B&B) framework for Integer Programming (IP) naturally provides an appealing ground for machine learning. At the same time, addressing one of the key heuristic decisions B&B relies on - namely, variable selection - poses many challenges for machine learning models. We propose a novel way to model the temporal complexity of B&B and the role of its diverse though interconnected components. We experiment on a baseline architecture, and highlight its flexibility to accommodate tools and insights from both IP and Deep Learning domains.

**4 - Bounding and Counting Linear Regions of Deep Neural Networks**

Thiago Serra, Carnegie Mellon University, Pittsburgh, PA, United States, Christian Tjandraatmadja, Srikumar Ramalingam

We study the number of linear regions that piecewise linear functions represented by neural networks can attain, both theoretically and empirically. We present (i) tighter bounds for the maximum number of linear regions on rectifier networks, which are exact for inputs of dimension one; (ii) a first upper bound for multi-layer maxout networks; and (iii) a first method to perform exact enumeration of the linear regions by modeling the DNN as a mixed-integer program. These bounds come from leveraging the dimension of the space defining each linear region and they indicate that, for a same number of units, the dimension of the input determines if shallow or deep networks have more linear regions.

**SC05**

North Bldg 122B

**Semidefinite Optimization II**

Sponsored: Optimization/Linear and Conic Optimization

Sponsored Session

Chair: Nathan Krislock, Northern Illinois University, DeKalb, IL, 60115-2888, United States

**1 - Low-Rank Matrix Completion (LRMC) using Nuclear Norm (NN) with Facial Reduction (FR); Applications to Robust Principal Component Analysis**

Henry Wolkowicz, University of Waterloo, Combinatorics & Optimization, Waterloo, ON, N2L 3G1, Canada

Minimization of NN is often used as a convex relaxation for solving LRMC problems. This can then be solved using semidefinite programming (SDP). The SDP and its dual are regular. FR has been successful in regularizing degenerate problems. Here we take advantage of the structure at optimality for the NN minimization and show that even though strict feasibility holds, the FR framework can be successfully applied to obtain a proper face that contains the optimal set and even improves on the NN relaxation. We include numerical tests for both exact and noisy cases.

**2 - Finding the Relative Interior of Spectrahedra with Applications to Facial Reduction and Matrix Completion Problems**

Stefan Sremac, University of Waterloo, Waterloo, ON, Canada

A spectrahedron is the intersection of an affine manifold with the cone of positive semidefinite matrices. In this talk we present an approach to finding a matrix in the relative interior of a spectrahedron. We construct a parametric curve terminating at a matrix in the relative interior of the spectrahedron and present sufficient conditions for this limit point to be the analytic centre. We implement a path-following algorithm and discuss numerical performance on test spectrahedra having various singularity degrees. Finally, we conclude the presentation by discussing implications of the approach to positive definite Toeplitz completion problems.

**3 - BiqCrunch: Solving Binary Quadratic Problems Efficiently using Semidefinite Optimization**

Nathan Krislock, Northern Illinois University, Dept. of Mathematical Sciences, DeKalb, IL, 60115-2888, United States, Jérôme Malick, Frederic Roupin

BiqCrunch is a branch-and-bound solver using semidefinite optimization to compute high-quality bounds for binary quadratic problems, such as MaxCut, Max-k-Cluster, Maximum-Independent-Set, Exact Quadratic Knapsack, and the Quadratic Assignment Problem. BiqCrunch does not use an interior-point method for computing its bounds. Instead, an eigenvalue solver and a gradient-based method are used to compute tight bounds. We will discuss our bounding procedure and give an update on the new features and performance enhancements of the latest version of BiqCrunch.

**4 - Solving the Semidefinite Programming (SDP) Relaxation in BiqCrunch using an Augmented Lagrangian Method**

Ahmed Al-Jilawi, Northern Illinois University, DeKalb, IL, United States

We present our recent work in solving semidefinite relaxations of binary quadratic optimization problems in the BiqCrunch solver. The semidefinite relaxation gives us a high-quality bound on the optimal value of the binary quadratic optimization problem. We use an augmented Lagrangian method instead of the penalty method in BiqCrunch, giving us a bounding procedure that converges faster.

**SC06**

North Bldg 122C

**Computational Optimization**

Sponsored: Optimization/Computational Optimization and Software

Sponsored Session

Chair: Hande Benson, Drexel University, Philadelphia, PA, 19104, United States

Co-Chair: Robert J. Vanderbei, Princeton University, Princeton University, Princeton, NJ, 08544, United States

**1 - Augmented Lagrangian - Fast Projected Gradient Method for Convex Quadratic Problems**

Igor Griva, George Mason University, Fairfax, VA, United States

We consider an augmented Lagrangian - fast projected gradient method for convex quadratic problems with linear constraints and simple bounds and discuss its convergence properties.

## 2 - Improving Exploration in Population-based Metaheuristics using Fading Consensus: Application to PSO

Xin Su, Arizona State University, Tempe, AZ, United States,  
Theodore P. Pavlic

Simple averaging protocols on fault-prone networks can exhibit long periods of quasi-stability punctuated by large group-level jumps. Although communication theorists view these recently observed jumps as pernicious, we propose using them to augment population-based metaheuristics to improve search ergodicity in multiextremal optimization. We demonstrate this approach with faded consensus particle swarm optimization (FC-PSO), which is a multi-agent optimization algorithm that improves the performance of PSO while potentially decreasing the number of required function evaluations as well.

## 3 - Distributed Non-linear Optimization under Non-separable Constraints: A Low-communication Approach with a Power Systems Example

Theodore P. Pavlic, Assistant Professor, Arizona State University,  
ASU - CIDSE, P.O. Box 878809, Tempe, AZ, 85287-8809,  
United States

Economic dispatch, matching generator operation levels to customer demands over a network, is the optimal diet problem of power systems. Non-linear cost functions and non-separable demand constraints usually require centralized solutions or decentralized approaches with high amounts of communication (e.g., bidding with Lagrange multipliers). In this talk, I introduce a distributed primal-space approach that converges to a bounded set of the optimizer with no direct communication between generators and self adjusts to changes in demands without broadcasting new parameters to every generator.

## 4 - Efficient LP Algorithms for which the Dense Constraint Matrix has a Sparse Factorization

Robert J. Vanderbei, Princeton University, Operations Research &  
Financial Engineering, 209 Sherrerd Hall, Princeton, NJ, 08544,  
United States

In linear programming, it is sometimes the case that the constraint matrix  $A$  is fairly dense but has a known sparse factorization. A few different methods for exploiting this sparsity in the context of interior-point methods will be presented and compared. The same ideas can be extended naturally to interior-point methods for nonlinear programming.

## 5 - Motion Planning for Autonomous Vehicles using MINLP

Hande Benson, Drexel University, Department of Decision  
Sciences, 3141 Chestnut Street, Philadelphia, PA, 19104,  
United States

We will present a mixed-integer nonlinear programming model, its centralized and decentralized solution, for motion planning in fleets of autonomous vehicles under communication constraints.

## ■ SC07

North Bldg 123

### Uncertainty and Network Resilience

Sponsored: Optimization/Network Optimization

Sponsored Session

Chair: Zhijie Dong, Texas State University, San Marcos, TX, 78640,  
United States

## 1 - Interdependent Network Functionality and Recovery for Community Resilience

Charles D. Nicholson, University of Oklahoma, 202 West Boyd,  
Room 124, Norman, OK, 73019, United States, Weili Zhang,  
Naiyu Wang, Peihui Lin, Xianwu Xue

A framework is presented to estimate building functionality loss and utility recovery in a community following a hazard. Analysis includes spatial distribution of physical damages to both buildings and utility infrastructure; utility disruptions deriving from the cascading failures; and the recovery of the utility system. The framework couples stochastic functionality analyses of physical systems and hazard response characteristics to provide a rich array of information for hazard mitigation and resilience planning. An earthquake scenario in Shelby Co., TN illustrates the framework.

## 2 - Resilience Quantification in Global Maritime Networks

Elise Miller-Hooks, George Mason University, 208 Rosalie Cove Ct,  
Silver Spring, MD, 20905, United States, Ali Asadabadi

Ports are critical components of the global supply chain, supplying key connections between land- and maritime-based transport modes. They operate in cooperative, but competitive environments wherein individual port throughput is linked through an underlying transshipment network. Building on concepts of stochastic equilibrium problems with equilibrium constraints, this presentation models and analyzes protective investment strategies aimed at enhancing resilience to disruption from a host of potential future damage scenarios while protecting each port's market share.

## 3 - Restoration Crew Routing Problem under Incomplete Information

Kash Barker, University of Oklahoma, 202 W. Boyd St., Room 124,  
Norman, OK, United States, Kash Barker

We consider the problem of restorative capacity enhancement problem in an infrastructure network which is interconnected with a routing network through which restoration crews are dispatched. The output will be a set of synchronized routes formed by planning and scheduling restorative efforts for infrastructure networks. Along with the uncertainty and urgency during post-disruption situations, considering the routing network disrupted may result in the limited information on the requirements for network restoration. To deal with this case, we propose a stochastic restoration crew routing problem to improve the compatibility of the model with the real-time conditions.

## 4 - Uncertainty-aware Routing of Aerial Sensors for Infrastructure Damage Inspection

Andrew Lee, Massachusetts Institute of Technology, Cambridge,  
MA, United States, Mathieu Dahan, Saurabh Amin,  
Cynthia Barnhart

We present an approach to actively inspect urban networks facing risk of disruptions due to natural events using small Unmanned Aerial Systems (sUAS). Information from fixed sensors and environmental features are used to predict the number and type of failures in different spatial regions. These predictions are used to achieve prioritized plans for routing repair vehicles and sUAS. This entails incorporating uncertainties in the distribution of failure events and travel times into a network inspection problem and a vehicle routing problem, and sequentially solving them. We illustrate our approach using data from Houston's drainage network inspection in the aftermath of Hurricane Harvey.

## ■ SC08

North Bldg 124A

### Joint Session OPT/Practice Curated: Network Optimization Models in Routing and Communications

Sponsored: Optimization/Network Optimization

Sponsored Session

Chair: Tachun Lin, Bradley University, Peoria, IL, 61625, United States

## 1 - Consistent Aircraft Fleeting and Routing among Schedule Periods

Zhili Zhou, United Airlines, 233 S. Wacker Drive, 5th Floor,  
Chicago, IL, 60606, United States

Commercial airlines invest in international markets, which gain revenues compatible with its domestic counterpart. For international services, airlines change flights and markets in different schedule periods. To reduce the operational burdens, we address the fleet assignment and aircraft routing consistency problem between two schedule periods with the objective to minimize the changes of fleets on served markets and routes. We explore the column-and-row algorithm under a cross-layer network setting for this airline scheduling problem. Preliminary experiment results demonstrate the improvement of scheduling consistency between schedule periods.

## 2 - On Routing Unmanned Aerial Vehicles for Surveillance and Reconnaissance Activities

Cai Gao, University at Buffalo, Buffalo, NY, 14260, United States,  
Jose Luis Walteros

We tackle a variation of the Close-enough Traveling Salesman Problem where the salesman is accounted for visiting a node if he traverses a precalculated distance through a circular area surrounding each node. This variation arises in the context of unmanned aerial vehicle (UAV) routing where a UAV collects information from a set of targets, while minimizing detection risks. We provide a mixed-integer formulation and solve it using Benders Decomposition. We enrich our approach by introducing a set of lifting algorithms to strengthen the optimality cuts generated by the proposed decomposition and a k-opt heuristic in the style of the classic Lin-Kernighan algorithm to generate better lower bounds.

## 3 - 5G Hierarchical Network Slicing with Uncertain Demands

Tachun Lin, Bradley University, 1501 W. Bradley Ave,  
Bradley Hall 171, Peoria, IL, 61625, United States

Network slicing, a key enabling technology for 5G development, creates concurrently dedicated and independent virtual networks and virtual network services for tenants on a common physical infrastructure platform. Compared with early works targeting single-domain physical infrastructure and demand-driven virtual network construction, we present in this talk multi-domain network slicing jointly with the construction of network functions' forwarding graph. We discuss random tenant choices and the respective resource allocation based on traffic/demand uncertainty under a cross-layer network topology.

#### 4 - A Real-time Relocation Strategy for Station Based Autonomous Electric Vehicle Sharing System

Li Li, PhD Candidate, New York University, New York, NY,  
United States, Saif Eddin G. Jabari

This paper puts forward a distributed rebalance strategy for station based autonomous electric vehicle sharing system. The max-weight algorithm is adopted and the queue stability of the network is guaranteed. The rebalance decision is made by each station independently, and only local information, e.g. queue length of neighboring stations, is required for decision making. Hence the rebalancing strategy is able to be implemented in real time, regardless of how big the network size is. Another advantage of this algorithm is that it requires no knowledge of the demands, and can achieve the maximum throughput of the whole network.

## ■ SC09

North Bldg 124B

### First-order Methods in Structured Non-convex Optimization

Sponsored: Optimization/Nonlinear Programming  
Sponsored Session

Chair: Paul Grigas, UC Berkeley, Berkeley, CA, 94720-1777,  
United States

#### 1 - Convergence to Second-Order Stationarity for Constrained Non-Convex Optimization

Meisam Razaviyayn, University of Southern California,  
3715 McClintock Ave, Los Angeles, CA, 90089, United States,  
Maher Nouiehed

We consider the problem of finding a second-order stationary point of a linearly constrained non-convex optimization problem. We show that, unlike the unconstrained scenario, the vanilla projected gradient descent algorithm fails to escape saddle points even in the presence of a single linear constraint. We then propose a trust region algorithm for linearly constrained optimization problem which converges to second order stationary points. Our algorithm is the first optimization procedure which can converge to  $\epsilon$ -first order stationary points of a non-manifold constrained optimization problem in  $\tilde{O}(\epsilon^{-3/2})$  iterations, and at the same time can escape saddle points under strict saddle property.

#### 2 - Gradient Boosting Machine: New Insights, Analysis and Algorithms

Haihao Lu, Mathematics Department and Operations Research Center, MIT Rahul, Sloan School of Management, MIT

Gradient Boosting Machine (GBM) is a powerful supervised learning algorithm, and has routinely featured as a top algorithm in Kaggle competitions and the KDDCup. It constructs additive models by greedily fitting a simple parameterized function (weak learner) to the current “residuals” at each iteration. In spite of the usefulness of GBM in practice, there is a huge gap between its theoretical understanding and the practical implementation. In this work, we propose Randomized Gradient Boosting Machine (RGBM), a new variant of GBM, in which we randomly picks a subset of weak learners and choose the best fit among them. A special case of RGBM corresponds to the column subsampling heuristic implemented in XGBoost. We show in theory that this approach is equivalent to a random-then-greedy coordinate descent in the coefficient space and/or a stochastic mirror descent in the “residuals” space. With such understanding, we derive novel, comprehensive computational guarantees for RGBM by using techniques of first-order methods in convex optimization, which as a special case significantly improve the traditional convergence rate for GBM as well. As a byproduct, such understanding also leads to a natural step-size rule as an efficient replacement of the line-search step-size rule in GBM.

#### 3 - Primal-dual Optimization for Online Advertising

Alfonso Lobos Ruiz, UC Berkeley, IOR, 4141 Etcheverry Hall,  
Berkeley, CA, 94720, United States, Paul Grigas

We propose and study non-convex optimization problems that arise in the context of online advertising, a multi-billion-dollar industry involving multiple ad-exchanges as well as other players. We propose a general primal-dual algorithmic scheme, and we identify a fairly general set of sufficient conditions that hold for several auction types such that our dual formulation obtains the same optimal value as the original non-convex formulation. In the context of the management of a Demand-Side Platform (DSP), we demonstrate how our offline optimization model and algorithm leads to an implementable policy by a DSP which we applied in both artificial and real data showing the value of our approach.

#### 4 - Generalization Error Bounds of SGD with Probabilistic Guarantee for Nonconvex Optimization

Yingbin Liang, The Ohio State University, 606 Dreese Lab,  
2015 Neil Avenue, Columbus, OH, United States, Yi Zhou,  
Huishuai Zhang

The success of deep learning has led to a rising interest in the generalization property of the stochastic gradient descent (SGD) method, and stability is one popular approach to study it. In this work, we characterize the on-average stability of the iterates generated by SGD in terms of the on-average variance of the stochastic gradients, and establish various generalization error bounds with probabilistic guarantee for SGD for nonconvex loss functions. With strongly convex regularizers, we further establish the generalization error bounds for nonconvex loss functions under proximal SGD with exponential concentration in probability.

## ■ SC10

North Bldg 125A

### MSOM Data Challenge Competition

Sponsored: Manufacturing & Service Oper Mgmt  
Sponsored Session

Chair: Gad Allon, University of Pennsylvania, 3730 Walnut Street,  
Philadelphia, PA, 19104, United States

#### 1 - MSOM Data Driven Research Challenge Finalists

Gad Allon, University of Pennsylvania, 3730 Walnut Street,  
Philadelphia, PA, 19104, United States

In this competition, researchers compete by building econometric models or data driven models using real data either to address some of the suggested questions below, or address questions of their own interest. The session will feature the finalists in the challenge.

## ■ SC11

North Bldg 125B

### Joint Session MSOM/Practice Curated: Empirical Topics in iFORM

Sponsored: Manufacturing & Service Oper Mgmt/iFORM  
Sponsored Session

Chair: Alex Yang, London Business School, London Business School

Co-Chair: Nitish Jain, London Business School, London, NW1 4SA,  
United Kingdom

#### 1 - Retailer Initiated Inventory-based Financing

Weiming Zhu, IESE Business School, Avenida Pearson 21,  
Barcelona, 08034, Spain, Wei Luo

We study a innovative financing scheme in which a large retailer provides short-term financing to a small retailer using the inventory of the small retailer as collateral. We analyze the effectiveness of such financing scheme and explore their impact on operational decisions and contract design.

#### 2 - Buyer Preferred Commodity Price Risk Allocation: A Theoretical and Empirical Investigation of the BMW Supply Chain

Panos Markou, Cambridge Judge Business School, Cambridge,  
United Kingdom, Daniel S. Corsten, Panos Kouvelis, Danko Turcic

Downstream manufacturers are exposed to volatile commodity prices through their suppliers, and information asymmetry often means that they are disadvantaged in seeing true prices in opaque markets. We formalize a model of BMW's supply chain, generate several predictions of how contracts should be allocated to suppliers under information asymmetry, and test these using a proprietary data set comprising contracting terms from 1,600 suppliers.

#### 3 - Operational Disruptions and the Value of Credible Control Systems

William Schmidt, Cornell University, 314 Sage Hall, Ithaca, NY,  
14850, United States, Ananth Raman

Operational disruptions can impact a firm's risk, which manifests in a host of operational issues, including a higher holding cost for inventory, a higher financing cost for capacity expansion, and a higher perception of the firm's risk among its supply chain partners. We empirically examine whether firms can meaningfully reduce the impact on their risk by implementing and credibly attesting to having effective internal control systems.



#### 4 - Supply Chain Network Structure and Environmental Information Disclosure

Marcus A. Bellamy, Rafik B. Hariri Building, 595 Commonwealth Avenue, Boston, MA, 02215, United States, Suvrat Dhanorkar, Ravi Subramanian

Recognizing that supply network structure has implications for a focal firm's ability to access environmental information embedded in its supply network, this paper draws on structural, environmental, and financial data from Bloomberg to test the relationship between a focal firm's supply network structure and its extent of environmental information disclosure.

### ■ SC12

North Bldg 126A

#### Joint Session Frontiers/Practice Curated: Statistical Learning and Optimization

Emerging Topic: OR Frontiers

Emerging Topic Session

Chair: Emma Frejinger, Université de Montréal, Montréal, QC, H3C 3J7, Canada

##### 1 - Learning MILP Resolution Outcomes before Reaching Time-limit

Andrea Lodi, École Polytechnique de Montréal, Montréal, QC, Canada, Martina Fischetti, Giulia Zarpellon

The solution of some MILPs still presents challenges for solvers and may require hours of computations, so that a time-limit is often provided by the user. Nevertheless, it could be useful to get a sense of the optimization trends after only a fraction of the time-limit, and ideally be able to tailor the use of the remaining solution time in a more strategic way. Looking at the evolution of a partial branch-and-bound tree for a MILP, up to a certain fraction of the time-limit, we aim to predict whether the problem will be solved to proven optimality before timing out. We exploit Machine Learning tools, and summarize the progress of a MILP solution process to cast a prediction within a classification framework.

##### 2 - Optimizing Decision Diagrams Size and Bound via Reinforcement Learning

Louis-Martin Rousseau, École Polytechnique de Montréal, Cp 6079 Succ Centre-Ville, Montréal, QC, H3C 3A7, Canada, Quentin Cappart, David Bergman

Decision Diagrams are a recent technology enhancing optimization methods. They can be used in Integer Programming for tightening relaxation bounds. Their performances are highly dependent on the variable ordering chosen. Finding an optimal ordering is NP-complete. Recent research in Machine Learning has also shown that reinforcement learning can be used for solving NP-hard problems. Following this trend, we propose to use a similar approach in order to reduce the size of Decision Diagrams.

##### 3 - Learning Heuristics for the TSP by Policy Gradient

Yossiri Adulyasak, HEC Montréal, 3000 Cote-Sainte-Catherine, Montreal, QC, H3T 2A7, Canada, Michel Deudon, Pierre Cournut, Alexandre Lacoste, Louis-Martin Rousseau

We extend the neural combinatorial optimization framework to solve the traveling salesman problem (TSP). The neural network is trained using reinforcement learning to predict a distribution over city permutations. We designed our own critic to compute a baseline for the tour length which results in more efficient learning. We further enhance the solution approach with the well-known local search heuristic and the approach could outperform a high performance heuristic (OR-Tools). Our approach based on machine learning techniques could learn good heuristics which, once being enhanced with a simple local search, yield promising results.

##### 4 - A Machine Learning Algorithm for Fast Prediction of Solution Descriptions to an ILP

Emma Frejinger, Université de Montréal, FAS, Pavillon Andre-Aisenstadt, Montreal, QC, H3C 3J7, Canada, Eric Larsen, Sébastien Lachapelle, Yoshua Bengio, Simon Lacoste-Julien, Andrea Lodi

We propose a methodology to predict descriptions of solutions to discrete stochastic optimization problems in short computing time. We approximate the solutions based on supervised learning and the training dataset consists of a large number of deterministic problems that have been solved independently (offline). Uncertainty regarding a subset of the inputs is addressed through sampling and aggregation methods. Our application concerns booking decisions of containers on double-stack trains. The results show that deep learning algorithms make predictions high accuracy in milliseconds or less.

### ■ SC13

North Bldg 126B

#### Healthcare Management: Meet the Editors

Sponsored: Manufacturing & Service Oper Mgmt/Healthcare Operations

Sponsored Session

Chair: Nicos Savva, London Business School, London, NW1 4SA, United Kingdom

Co-Chair: Susan F. Lu, Purdue University, Purdue University, West Lafayette, IN, 47907, United States

##### 1 - Healthcare Operations Management at POM

Sergei Savin, The Wharton School, 570 Jon M. Huntsman Hall, 3730 Walnut Street, Philadelphia, PA, 19104, United States

The POM Journal has maintained a strong tradition of publishing high-quality research in healthcare operations. The talk will review the mission of the Healthcare Operations Management Department at POM and the types of papers published in recent years.

##### 2 - Healthcare Operations Management at OR

Ozlem Ergun, Northeastern University, Mechanical and Industrial Engineering, Boston, MA, 02115, United States

The Policy Modeling and Public Sector OR area seeks papers that define important problems and use innovative mathematical models and analytics to solve them for improving outcomes. Especially welcome are manuscripts that utilize data to develop original models linking the design and operations of public programs and systems to recognizable policy outcomes and recommendations. Priority is given to papers that present novel and convincing data-driven model-based analyses of issues likely to generate widespread public interest, awareness, and impact.

##### 3 - Introduction of the New Healthcare Management Department of Management Science

Stefan Scholtes, University of Cambridge

Management Science has recently introduced a new department of Healthcare Management. I will introduce the new department and its editorial statement.

##### 4 - MSOM Submissions Perspective on Health Care Management Research

Morris A. Cohen, Professor, University of Pennsylvania, 546 Huntsman Hall, 3730 Walnut Street, Philadelphia, PA, 19104, United States

This presentation will provide an overview of the historical record of submissions to the Service Operations Department of MSOM that fall in to the area of Healthcare Management. This will include a summary of the volume and outcome of papers submitted to the department during the period 2016 to the present. We will also review the major topic areas, source (authors affiliation), reasons for acceptance or rejection, and the nature of the research (i.e. analytical, empirical, policy, other). The presentation will conclude with observations on trends in healthcare management research as well as challenges, and opportunities for future research directions as suggested by the MSOM experience.

##### 5 - Healthcare Management at the INFORMS Journal on Computing

Paul Brooks, Virginia Commonwealth University, Dept of Stat Sci and OR, P.O. Box 843083, Richmond, VA, 23284, United States

The Applications in Biology, Medicine, & Healthcare area of the INFORMS Journal on Computing publishes articles and welcomes manuscripts in the area of healthcare management. We seek manuscripts that include OR, computing, and a relevant application, and provide a significant contribution in at least one of these or in a combination.

## ■ SC14

North Bldg 126C

**Joint Session MSOM/Practice Curated:  
Empirical OM in Services**

Sponsored: Manufacturing &amp; Service Oper Mgmt/Service Operations

Sponsored Session

Chair: Carri Chan, Columbia Business School, New York, NY, 10027, United States

Co-Chair: Fanyin Zheng, Columbia University, New York, NY, 10027, United States

**1 - Component Sharing and Recalls: An Empirical Study in the Auto Industry**

Kamalini Ramdas, London Business School, A215 Sussex Place, Regent's Park, London, NW1 4SA, United Kingdom

Automakers often share components - such as brakes, engines or outer body panels - across models in their product lines, in any year and across years. We examine how such component sharing impacts product recalls, using US government recalls data and detailed data on automakers' component sharing strategies in the US market.

**2 - The Combined Effect of the Information Provision and the Randomized Reward on Patients' Satisfaction**

Danqi Luo, Stanford Graduate School of Business, 655 Knight Way, Stanford, CA, 94305, United States, Mohsen Bayati, Erica Plambeck

This work looks at the problem of information provision on wait time in the emergency department. What kind of information schemes should be provided to the low-acuity patients, considering patients' own satisfaction and the waiting externalities on other patients? The effect of varies delay announcement schemes on patients' satisfaction level and pain level will be looked.

**3 - The Impact of Primary Care Provider Availability on Patient Care**

Hessam Bavafa, Wisconsin School of Business, 4284C Grainger Hall, 975 University Avenue, Madison, WI, 53706, United States, Christian Terwiesch

Emergency room (ER) overcrowding and overuse are significant problems in the United States, and prior studies have shown that a large portion of ER patients could have been treated by a primary care provider. If this is the case, why do patients spend hours waiting in the ER for a problem that their primary care physician could have addressed? One common answer is that primary care providers are too busy to provide timely appointments, making the ER a more attractive alternative for their patients. In this paper, we use a large dataset from the Veterans Health Administration to shed light on this claim.

**4 - Structural Estimation of Intertemporal Externalities on ICU Admission Decisions**

Fanyin Zheng, Columbia University, Columbia Business School, 412 Uris Hall, New York, NY, 10027, United States, Carri Chan

Patient care in capacity-constrained hospital units sometimes results in scenarios where the demanded quantity and level for care exceeds immediate availability, which may impact patient outcomes as well as economic outcomes. In this paper, we study the intertemporal externalities on Emergency Department patients' Intensive Care Unit admission decisions. In particular, we study how admitting a patient in the current period affects the system status, and, in turn, its ability in admitting another patient with possibly more severe conditions in the next period. We take the structural estimation approach which allows us to estimate the intertemporal externalities from data.

## ■ SC15

North Bldg 127A

**Innovation in Services**

Sponsored: Manufacturing &amp; Service Oper Mgmt/Service Operations

Sponsored Session

Chair: Pnina Feldman, Boston University, Boston, MA, 02215, United States

**1 - Controlling Congestion when Consumers Choose Their Service Time**

Pnina Feldman, Boston University, 595 Commonwealth Ave, Boston, MA, 02215, United States, Ella Segev

In many service environments consumers have a need for service and choose how long they want to use it. We propose alternative mechanisms, such as imposing a limit for the time spent in service and charging a price per unit of time, for controlling congestion in such settings. We investigate their optimality

for maximizing firm's profits as well as consumer and social welfare.

**2 - Persuading Customers to Buy Early**

Ramandeep Randhawa, University of Southern California, Los Angeles, CA, United States, Shobhit Jain, Kimon Drakopoulos

Retailers tend to have more information than customers on product availability. This leads to the natural question of how can a firm communicate this information in a profitable manner. We use a Bayesian Persuasion framework to model this information provisioning game. We find that public information provisioning has limited value, however, personalized information provisioning has significant value. Somewhat surprisingly, we find that personalized information provisioning has attributes very similar to personalized pricing.

**3 - The Boundaries of Operational Transparency**

Laurens G. Debo, Dartmouth College, 100 Tuck Hall, Hanover, NH, 03755, United States, Cuihong Li, Ryan Buell

Recent research has suggested that providing operational transparency from customers to employees can increase customers' perceptions and appreciation of employee effort, which in turn boosts customer perceived value. In this talk, we discuss mechanisms through which operational transparency might backfire. We test out the strength of these mechanisms in a controlled laboratory setting.

## ■ SC16

North Bldg 127B

**MSOM Sustainable Operations: Daniel Ying's Session**

Sponsored: Manufacturing &amp; Service Oper Mgmt/Sustainable Operations

Sponsored Session

Chair: Yen-Ting (Daniel) Lin, University of San Diego, San Diego, CA, 92110, United States

**1 - Supplier Development in a Multitier Supply Chain**

Timothy Kraft, MIT Sloan School of Management, Cambridge, MA, United States, Ozgen Karaer, Pinar Yalcin

We study a buyer's strategy to develop the quality capabilities of a tier-1 and a tier-2 supplier. We consider how the buyer's cost-sharing decisions and the suppliers' quality decisions are impacted by the market opportunity for improved quality and the division of the supply chain margin between the three parties. We find if the market opportunity is such that the buyer develops only one supplier, then he should share costs with the supplier that captures the higher portion of the margin. If instead the market opportunity is greater and he invests in both suppliers, then he should instead share a larger fraction of the cost to build quality with the supplier that captures the lower portion of the margin.

**2 - The Danger of Tightening Standards in Driving Carmakers' Non-compliance Behavior**

Kejia Hu, Vanderbilt University, 300 Ashcroft Pl, Nashville, TN, 37215, United States, Sunil Chopra, Yuche Chen

Using a 14-year on-road vehicle emission dataset, we confirm a causal impact from tightening emission standards on carmakers' noncompliance behavior.

**3 - The Environmental Impact of Online Grocery Retailing**

Ekaterina Astashkina, INSEAD, Boulevard de Constance, Fontainebleau, 77305, France, Elena Belavina, Simone Marinesi

We explore the environmental impact of the online grocery retailing. We build a stylized three-echelon model of traditional and online fresh grocery chains. We identify the drivers of grocery retail carbon footprint at the consumer, retail, and supplier tiers, incorporating food waste and transportation emissions. We analytically characterize when online presence is environmentally beneficial or detrimental, and isolate the three drivers by which online presence can hurt the environment: retail inventory decentralization, excessive household food waste, or last-mile travel. Calibration of the model suggests that, in all practical cases, online presence reduces total emissions.

**4 - Supplier Centrality and Auditing Priority in Socially-responsible Supply Chains**

Jiayu Chen, The University of Texas at Dallas, 800 W. Campbell Road, Richardson, TX, 75080, United States, Anyan Qi, Milind Dawande

Most supply networks are characterized by firms sourcing from multiple suppliers and suppliers serving multiple firms, thus resulting in suppliers who differ in their degree centrality, i.e., the number of firms they supply to. In such networks, any negative publicity from suppliers' noncompliance of socially-responsible practices can significantly damage the reputation of the buyers. To mitigate this impact, firms preemptively audit suppliers, although resource and time considerations typically restrict the number of suppliers a firm can audit. We explore how the degree centrality of the suppliers affect the socially-responsible supply chains and offer several novel and useful insights.

## ■ SC17

North Bldg 127C

**Supply Chain Management at JD.com**Sponsored: Manufacturing & Service Oper Mgmt/Supply Chain  
Sponsored Session

Chair: Zuo-Jun Max Shen, University of California Berkeley, Berkeley, CA, 94720-1777, United States

Co-Chair: Di Wu, JD.com, Mountain View, CA, 94043, United States

**1 - An Approximation Algorithm for Joint Replenishment-and-Allocation Problem**

Meng Qi, University of California, Berkeley, 1911A Berkeley Way, Berkeley, CA, 94704, United States, Rong Yuan, Di Wu, Max Shen

We study the joint replenishment-and-allocation inventory management problem in the context of JD.com's two-echelon inventory network. Different from the traditional two-echelon system, inventories at the upper-level warehouse are used to fulfill customer orders for a major city as well as transshipped to warehouses that used to fulfill orders for small cities and rural area. We formulate the problem as a multiple period decision problem and derived an approximation algorithm with worst-case bound. We demonstrate the effectiveness of the proposed algorithm through an extensive numerical study.

**2 - Matrix Factorization with Missing Data for Improving Accuracy of Probabilistic Demand Forecasting**

Di Wu, JD.com, 675 E. Middlefield Rd, Mountain View, CA, 94043, United States, Xiaoyue Li, Yi Pan

Demand forecast, as a classical time series problem, is crucial for e-commerce supply chain management. The performance of sales forecast has significant impact on revenue and operation cost. At the same time, missing or incomplete sales data commonly exists in the historical data which causes traditional time series models to be less effective. This paper describes an algorithm developed based on matrix factorization that specifically designed to handle missing-value issues and demonstrates its usage for demand forecast for JD.com.

**3 - Understanding the Value of Fulfillment Flexibility in an Online Retailing Environment**

Yehua Wei, Boston College, 140 Commonwealth Avenue, Chestnut Hill, MA, 02467-3809, United States, Levi DeValve, Rong Yuan, Di Wu

We propose a two-echelon inventory fulfillment model for a large online retailer, containing a large central distribution center (DC), and  $N$  smaller local DCs, to study the value of fulfillment flexibilities. Motivated by practical constraints, we propose a class of threshold fulfillment policies to effectively incorporate flexibilities at DCs. Based on our threshold policy, we estimate the savings on shipping costs and lost sales cost for a more flexible fulfillment structure considered by the online retailer.

**4 - Omni-Channel Online Fulfillment Threshold Policies**

Xin Chen, UIUC, 216C Transportation Building, 104 S. Mathews Avenue, Urbana, IL, 61801, United States, Ebrahim Arian, Rong Yuan, Di Wu

We consider inventory models in which online demands are fulfilled by physical stores. We focus on the threshold type of policies to control the amount of online demands to be accepted and compare their performances. The potential impacts of our models/policies are illustrated on JD.com's 7fresh business.

**5 - Product Placement Optimization Using Parametric Cuts**

Titouan Jehl, University of California - Berkeley, Berkeley, CA, United States, Yuhui Shi, Di Wu, Max Shen

E-Commerce companies use forward distribution centers (FDC) that are closer to customers distance-wise to fulfill orders in a timely manner. However, due to the capacity, it is impossible to store every item vended in the FDC. If an customer order contains items not stored as inventory, it comes in several packages (called order split), leading to a worse consumer shopping experience and higher operations costs. The proposed method in this research reduces the number of split orders by building an item-order graph and solving for the optimal assortment problem using parametric cut over the graph, which can reflect consumers' co-purchase behaviors.

## ■ SC18

North Bldg 128A

**Operations Planning in Supply Chain**Sponsored: Manufacturing & Service Oper Mgmt/Supply Chain  
Sponsored Session

Chair: Sean Zhou, Chinese University of Hong Kong, Shatin N. T, Hong Kong

**1 - Multilocation Newsvendor Problem: Centralization and Inventory Pooling**

Sean Zhou, Chinese University of Hong Kong, 12 Chak Cheung Street, Cheng Yu Tung Building, Shatin N. T, Hong Kong, Chaolin Yang, Zhenyu Hu

We study a multilocation newsvendor model with a retailer owning multiple retailing stores, each of which is managed by a manager who decides its order quantity for filling random customer demand of a product. The store managers and the retailer are all risk-averse while the managers are more risk-averse than the retailer. When there is inventory pooling, if the store managers are sufficiently more risk-averse than the retailer or the demands are very heavy-tailed, we find that inventory pooling brings less benefit than centralization.

**2 - Optimal Inventory Control on a Multi-Item Inventory Model with Partial Pricing Strategies**

Youyi Feng, Zaragoza Logistics Center, C/ Bari 55, Edificio Nayade 5 Plaza, Zaragoza, 50197, Spain

We study an inventory and pricing control on the multi-item inventory system with  $K = K_0 + K_1 + K_2$  products, among which there are  $K_0$  complementary products whose prices are controlled by the firm. Other  $K_1$  products and  $K_2$  products are complement and substitute to either of those  $K_0$  products, respectively. Demand functions for these products are linear with additive independent noises. We characterize optimal joint partial pricing and inventory control on all the products and compute optimal policy with an efficient algorithm. In addition, we demonstrate the firm views the economic relations between the products differently from what the customers do.

**3 - Dynamic Substitution Policy for Selling Multiple Products under Supply Uncertainty**

Chengzhang Li, Purdue University, West Lafayette, IN, United States, Qi Feng, Mengshi Lu, J. George Shanthikumar

We study a firm selling multiple substitutable products over a selling horizon of multiple periods. The firm faces replenishment cycles of fixed lengths with uncertain supply. In each period, when the random demands materialize, the firm may choose one product to meet the demand for another at a cost. Extending the notion of stochastic linearity, we show that the replenishment problem is concave via transformation. We design an efficient algorithm to determine the allocation policy that delivers close-to-optimal performance. We also show that restricting substitutions between products with adjacent characteristics can yield a benefit close to allowing full substitution among all products.

**4 - Effects and Mitigation of Natural Hazards in Retail Networks**

Jorge Garc a Castillo, Massachusetts Institute of Technology, Cambridge, MA, United States, Jarrod D. Goentzel

Knowing the impact of natural hazards is crucial to invest in mitigation. We cross sales and inventory from a retail network with emergency management data to quantify the variability in product and financial flows. We propose a two-stage multi-period inventory flow stochastic program to plan investment in buffer stock or real options contracts with suppliers that execute in declared emergencies. We show that a risk averse approach reduces worst-case cost by 15% while increasing average cost by 2%. We close by showing how various risk profiles shape the nature of investments.



## ■ SC19

North Bldg 128B

**Joint Session RMP/Practice Curated:  
Empirical Research in Revenue Management**

Sponsored: Revenue Management &amp; Pricing

Sponsored Session

Chair: Dan Zhang, University of Colorado, Leeds School of Business,  
University of Colorado, Boulder, CO

Co-Chair: Xiao Huang, Concordia University, Montreal, Quebec

**1 - How Does Price Volatility Influence Demand of Revenue  
Managed Goods?**Benny Mantin, University of Luxembourg, Luxembourg, L-1511,  
Luxembourg, Chiara Morlotti

We estimate the impact of price fluctuations on demand in the context of revenue-managed goods, first by introducing a new measure of price volatility and second by quantifying the effect on demand elasticity. Using airfare and sales data collected for 21 European route-pairs over five months, we carry out our empirical analyses (IV 2SLS regressions) revealing that as price volatility increases, consumers tend to buy less. We demonstrate how this can be integrated into the classical revenue management model (Expected Marginal Seat Revenue) to yield higher revenues.

**2 - Product Quality, Service and Pricing**Ruxian Wang, Johns Hopkins University, Carey Business School,  
100 International Dr, Baltimore, MD, 21202, United States,  
Shiliang Cui

We develop a unified framework to investigate firms' joint decisions on product quality, price and ancillary service, when they offer a line of products to consumers in a variety of monopolistic and competitive environments.

**3 - Psychological Overage and Underage Costs in Three-part Tariff  
Plans: Evidence from Bike-sharing Economy**Necati Terreyagolu, Georgia Institute of Technology, Scheller  
College of Business, 800 West Peachtree Street NW, Atlanta, GA,  
30308, United States, Brian S. Park, Eunhee Sohn

Three-part tariff plans are often the pricing choice for service providers. These plans involve a fixed subscription fee, which provides an allowance of free units, and a penalty fee for each unit above the allowance. We hypothesize that consumers' usage is determined not only by a psychological cost for passing the allowance (overage), but also by a psychological cost from ending the usage earlier than what is allowed after the paid penalty (underage). We test both costs using individual-level riding data from a bike-sharing company in New York City, and show that riding decisions are driven by the two psychological costs. We also show that the revenue effects of the psychological costs are significant.

**4 - Price to Gain or Price to Retain? An Empirical Study of Hotel  
Pricing and Customer Cancellation Behavior**Dan Zhang, University of Colorado, Leeds School of Business,  
University of Colorado, Boulder, CO, 80309, United States, Xiao  
Huang, Jian Wang

We use hotel transaction data to investigate the customer cancellation behavior. We show that cancellation rates are highly correlated with booking rates and the posted rates at the time of cancellation. We discuss the implications of this finding on hotel overbooking. Our results complement the empirical research on strategic customer behavior in revenue management and highlight the importance of accounting for the behavioral impact of pricing.

**5 - Payment Modes and Order Cancellation: Empirical Evidence from  
an Online Travel Agent in China**Huan Zheng, Shanghai Jiao Tong University, Management Science  
Department, 535 Fa Hua Zhen Rd, Shanghai, China, Zilin Hao,  
Junxiong Yin

Dynamic pricing is a widely adopted tool for Online Traveling Agencies. Consumers strategically respond to price fluctuations in various ways to maximize their utilities. In this study, we empirically explore how consumers choose different payment modes when booking hotel rooms, and strategically cancel their bookings from transaction data of a large Online Traveling Agency in China. Based on our two-period econometric model, we find that strategic consumers will keep monitoring price fluctuations and then decide whether they should cancel existing orders.

## ■ SC20

North Bldg 129A

**Design and Operations of Marketplaces**

Sponsored: Revenue Management &amp; Pricing

Sponsored Session

Chair: Yash Kanoria

Co-Chair: Abhinav Sinha, Columbia Business School, 3022 Broadway,  
New York, NY, 10027, United StatesCo-Chair: Fanyin Zheng, Columbia University, New York, NY, 10027,  
United States**1 - Engineering a Separating Equilibrium**John Joseph Horton, New York University-Stern, New York, NY,  
10012, United States, Ramesh Johari

This paper explores whether platform-created signaling opportunities can move designed markets to more desirable equilibria. In a large online labor market, buyers were given the opportunity to signal their relative preferences over price and quality. The intervention caused substantial sorting by sellers to buyers of the right "type." However, sellers clearly tailored their bids to the type of buyer they faced, bidding up against buyers with a high revealed willingness to pay. Despite this "markup," a separating equilibrium was sustained over time, suggesting buyers found revelation incentive compatible. We find evidence that informative signaling improved both matching efficiency and match quality.

**2 - Dog Eat Dog: Measuring Returns to Scale using a Digital  
Platform Merger**Andrey Fradkin, Massachusetts Institute of Technology,  
179 Prospect Street, Cambridge, MA, 02139, United States,  
Chiara Farronato

We study returns to scale in digital marketplaces by using proprietary data from the merger of the two largest peer-to-peer platforms for pet sitting services. The merger offers a unique opportunity to study this question because it is one of the few cases where platform size changes in a sudden and exogenous way, not caused by incremental adoption. In addition, the local nature of the services exchanged provide us with multiple city-level markets that are differentially affected by the merger. We quantify changes in the aggregate number of matches and their quality after the platform merger, and how efficiency gains are differentially distributed across platform users.

**3 - Optimal Growth in Two-sided Markets**Garrett Van Ryzin, Cornell University, Ithaca, NY, United States,  
Zhen Lian

We consider the problem of optimal growth in a two-sided market with both increasing and decreasing returns to scale. We show that in both cases faster growth is better and optimal policies involve large "subsidy shocks". Our results also show the optimal balance between supply and demand as markets grow.

**4 - Match Efficiency in Two-sided Platforms**Abhinav Sinha, Columbia Business School, New York, NY,  
United States, Yash Kanoria, Fanyin Zheng

We study the design of two-sided online marketplaces using recent transaction data from a large online platform. We are interested in estimating (i) the unobservable demand and (ii) the dependence of aggregate number of matches on macro-level market characteristics such as the total number of sellers and buyers in the market. Further, our aim is to run counterfactual analysis on platform design and recommend the best ways to improve matching efficiency and/or net profit. We introduce a matching function approach to capture search frictions in the market.

## ■ SC21

North Bldg 129B

**Machine Learning in Demand Modeling**

Sponsored: Revenue Management &amp; Pricing

Sponsored Session

Chair: Andrew Vakhutinsky, Oracle

**1 - Using Monte Carlo Simulations to Balance Supply and Demand in  
an On-demand Grocery Delivery Marketplace**Jagannath Putrevu, Instacart, 50 Beale St, 11th Floor, Instacart,  
San Francisco, CA, 94105, United States

Instacart uses a network of personal shoppers and drivers to shop for groceries and deliver them to our customers. For Instacart to continue growing rapidly, we want to capture as much demand as possible while keeping our costs low and our personal shoppers and drivers engaged on the marketplace. But this is easier said than done. On any given day, there are multiple factors that contribute to a large amount of variance, which makes this an extremely hard problem. This talk explores a simulation-based optimization methodology that we employed to

maximize delivery efficiency, minimize idle shopper hours and minimize orders lost due to lack of supply, all while managing the uncertainty.

## 2 - Dynamic Pricing with Sales- and Inventory-dependent Demand: The Effectiveness of Certainty-equivalent Approximation

Mengzhenyu Zhang, University of Michigan, Ann Arbor, MI, United States, Hyun-Soo Ahn, Christopher Ryan, Joline Uichanco

We study a pricing problem where future demand is influenced by past sales and/or product availability as well as price. Under this setting, the price of a product not only determines the revenue and demand in that period but also influences future demands. Hence, the role that a price decision plays is more complicated than most revenue management models where price only affects the sales in that period. We provide asymptotic results that illustrate the effectiveness of certainty-equivalent policies in these settings. We also analytically demonstrate the benefits of dynamic versus static pricing and characterize when it is revenue-optimal to underserve the market by restricting total supply.

## 3 - Joint Clustering of Retail Products and Customers

Andrew Vakhutinsky, Oracle Labs, 35 Network Drive, Sharon, MA, 02067, United States, Daniel Peterson

Cluster analysis of products and customers is useful for marketing and product targeting. Using a large dataset of retail transactions for millions of households across one year, we develop a probabilistic clustering of households and products that captures typical purchase behavior. Latent Dirichlet Allocation (LDA) is attractive for this application, because it allows a soft clustering. In this work demonstrate the shortcomings of naive application of LDA, present a few simple solutions that improve the product clusters dramatically, and discuss how metadata about the products and households can be used to further improve the clustering. We also compare results from other approaches.

## 4 - Score a Retail Store Location

Yihui Huang, Tsinghua University, Beijing, China, Chen Wang, Lei Zhao

Expected customer visits and sales are two important measures for a retail to decide whether to open a new store at a candidate location. Noticing different shopping behaviors of customers from different types of locations, e.g., shopping malls (S), crowd points (C), offices (O) and resident communities (R), we propose time-domain and frequency-domain models to predict these measures. We develop an expectation-maximization (EM) algorithm to learn the model parameters based on the data of existing stores and public data.

## SC22

North Bldg 130

## Mechanism Design, Networks, and New Markets

Sponsored: Revenue Management & Pricing

Sponsored Session

Chair: Ozan Candogan, University of Chicago, Chicago, IL, 27708, United States

## 1 - Optimal Commissions & Subscriptions in Networked Markets

Hongfan Chen, University of Chicago, 5050 S. Lake Shore Drive, S3417, Chicago, IL, 60615, United States, Ozan Candogan, Daniela Saban, John R. Birge

We consider a platform providing a marketplace to sellers and buyers of different types, whose compatibility is encoded in a bipartite network. With the platform only controlling commissions/subscriptions, we establish that, the platform may need to differentiate the charges to maximize revenues. We show that charging homogeneous commissions/subscriptions or charging to only one side of the market leads to heavy revenue loss in general. Under homogeneous value distributions, we provide a bound on the revenue loss in terms of the network structure. Finally, under some convexity assumptions, we show the revenue-maximizing equilibrium induces at least 2/3 of the maximum social welfare.

## 2 - Optimal Dynamic Matching under Lost Sales

Yun Zhou, McMaster University, 1280 Main Street West, Hamilton, ON, L8S 4M4, Canada, Zhiyuan Chen, Ming Hu

We consider a dynamic matching problem where the agents on one side, say supply side, are long-lived, and those on the other, say demand side, are impatient and will be lost if unmatched upon arrival. The matching reward is the multiplication of quality levels of agents in a match. In a centralized setting, we show that the optimal matching priority is different from assortative mating: it is optimal to prioritize high-quality supply over low-quality one to satisfy high-quality demand; however, for the low-quality demand, low-quality supply has a priority. We show how the decentralized matching process can be perfectly coordinated as the centralized one.

## 3 - Peer-to-Peer Trading of Usage Quotas

Behrooz Pourghannad, University of Minnesota, Minneapolis, MN, United States, Saif Benjaafar, Jian-Ya Ding

A growing number of businesses are being built around a model that provides customers access to a product or a service up to a specified amount or allowance. We study the impact of allowing customers to trade among themselves unused portions of their allowances and examine conditions under which peer to peer trading is beneficial to both the firms and consumers.

## 4 - Customer Learning and Competition for Online Sales of Durable Goods

Clark C. Pixton, Massachusetts Institute of Technology, Cambridge, MA, 02139, United States, Clark C. Pixton, Brigham Young University, Provo, UT, United States

Motivated by data from a large online retailer, we study online sales of durable goods, focusing on the effects of uncertainty about product quality and learning from customer reviews. We describe the nature of the tradeoff between learning product quality over time and substitution effects between products offered in the same category on the same website. We offer an alternate explanation for market dominance based on transient effects of a learning process which involves decisions under risk, and show that the learning is slower and market dominance more likely in higher price markets. We discuss implications of our model for games between platforms and sellers.

## SC23

North Bldg 131A

## Stochastic Control Problems in Finance

Sponsored: Finance

Sponsored Session

Chair: Tim Siu-Tang Leung, University of Washington, Seattle, WA, 98195-3925, United States

## 1 - Energy Storage and Trading

Daniel Mitchell, PhD, University of Minnesota, Kumar Muthuraman, Stathis Tompaidis, Long Zhao

We examine the problem of trading in a commodity that requires storage with transaction costs. We present an algorithm to find the optimal buying, selling and holding regions and consider extensions where prices exhibit seasonality, and when the inventory level can fluctuate randomly, such as a water reservoir that can be filled by rain and depleted through evaporation.

## 2 - Optimal Dynamic Basis Trading

Bahman Angoshtari, PhD, University of Washington, Seattle, WA, United States, Tim Siu-Tang Leung

We study the problem of dynamically trading a futures contract and its underlying asset assuming a stochastic basis model. We describe the basis evolution by a scaled Brownian bridge, but also incorporate the possibility of non-convergence at maturity. The optimal trading strategies are determined from a utility maximization problem under hyperbolic absolute risk aversion (HARA) risk preferences. By analyzing the associated Hamilton-Jacobi-Bellman equation, we derive the exact conditions under which the equation admits a solution and solve the utility maximization explicitly. A series of numerical examples are provided to illustrate the optimal strategies and examine the effects of model parameters.

## 3 - American Options under Periodic Exercise Opportunities

Kazutoshi Yamazaki, PhD, Kansai University, Kansai, Japan

We study a version of the perpetual American call/put option where exercise opportunities arrive only periodically. Focusing on the exponential Levy models with i.i.d. exponentially-distributed exercise intervals, we show the optimality of a barrier strategy that exercises at the first exercise opportunity at which the asset price is above/below a given barrier. Explicit solutions are obtained for the cases the underlying Levy process has only one-sided jumps.

## 4 - Dynamic Index Tracking and Exposure Control using Derivatives

Tim Siu-Tang Leung, University of Washington, Dept of Applied Mathematics, University of Wa, Lewis Hall #202, Seattle, WA, 98195-3925, United States

We develop a methodology for index tracking and risk exposure control using financial derivatives. Under a continuous-time diffusion framework for price evolution, we present a pathwise approach to construct dynamic portfolios of derivatives in order to gain exposure to an index and/or market factors that may be not directly tradable. Among our results, we establish a general tracking condition that relates the portfolio drift to the desired exposure coefficients under any given model. We also derive a slippage process that reveals how the portfolio return deviates from the targeted return.

## ■ SC24

North Bldg 131B

**Prosocial Behavior on Digital Platforms**

Sponsored: EBusiness

Sponsored Session

Chair: Xue Tan, Indiana University, Bloomington, IN, 47405, United States

**1 - Micro-giving: On the Use of Mobile Devices and Monetary Subsidies in Charitable Giving**

Dokyun Lee, Carnegie Mellon University, Tepper School of Business, 5000 Forbes Avenue, Pittsburgh, PA, 15213, United States, Dongwon Lee, Anandasivam Gopal

This study examines the effects of push notifications, monetary subsidies, and intertemporal choices of rewards on donation outcomes by individual users. Our experiments provide three main findings. First, push notifications have a remarkably high effect on donation behavior in terms of the decision to donate as well as donation amounts, especially for idle users. Second, offering rebates as economic incentives are more effective than offering matching grants, in particular for male consumers. Finally, while users are indifferent between receiving their rewards now versus later, users that are offered a rebate respond with greater alacrity when rewarded immediately rather than later.

**2 - Fundraising Patterns and Entrepreneurial Strategies in Crowdfunding**

Lusi Yang, National University of Singapore, 15 Computing Drive, COM2-01-02, Singapore, 117418, Singapore, Jungpil Hahn, David Lehman

This study aims to uncover the dynamics of crowdfunding by examining how fundraising patterns affect subsequent entrepreneurial strategies in managing the project during the funding process. Toward this goal, drawing insights from the behavioral theory of the firm, we identify two types of entrepreneurial strategies from potential courses of actions, i.e., exploitation and exploration, and examine the influence of concurrent fundraising performance on the two types of strategic actions.

**3 - You Run, I Donate: The Impact of Corporate Sponsorship in a Three-sided Charitable Platform**

Xue Tan, Indiana University, Kelley School of Business, 1309 E. 10th St, HH 4131, Bloomington, IN, 47405, United States, Lu Yan, Alfonso J. Pedraza-Martinez

This paper seeks to understand a three-sided marketplace where corporate sponsors individuals' charitable efforts by donating to charities based on the individuals' running miles captured by an mobile application. Using social media data that captured a natural experiment, we reveal the impact of announcing and showing gratitude to corporate sponsors.

**4 - Influence of Peer Based Monetary Incentive on Content Generation**

Zixuan Meng, University of Washington, Seattle, WA, 98115, United States, Yi-Chun Ho, Junjie Wu, Yong Tan

User-generated content has been widely studied in the past couple of years. Platforms have tried multiple methods to encourage the content generating behavior, and some have started motivating through monetary incentives. Using a unique setting where content consumers can voluntarily support writers through direct money transaction, we analyze how monetary incentive influences writers behavior. Our findings show that the availability of the monetary incentive encourages writers to increase both the quality and the quantity of writing. However, if the monetary incentive is below writers' expectation, writers can be demotivated.

## ■ SC25

North Bldg 131C

**Analytic Support for SMART Service Systems**

Sponsored: Service Science

Sponsored Session

Chair: Ralph D. Badinelli, Virginia Polytechnic Institute, Blacksburg, VA, 24061, United States

**1 - On Bias in AI Systems**

Rama Akkiraju, IBM, San Jose, CA, United States

Some argue that one must strive to build unbiased AI models by training AI models with comprehensive training datasets. In this talk, I'd argue that there is no such a thing as an 'unbiased' Machine Learning model. Instead of striving for unbiased machine learning models, a machine learning model must state its biases openly. Minimizing biases has to start with creating test datasets rather than with training datasets. I will provide a practitioner's point-of-view on mitigating biases in AI models.

**2 - Adaptive Decision Models for Smart Service Systems**

Ralph D. Badinelli, Virginia Polytechnic Institute, Dept of Business Information Tech (0235), Blacksburg, VA, 24061, United States

We describe an adaptive decision-modeling framework for integrating IoT and BDA into decision support for smart service systems. The sensing capabilities of IoT and the predictive capabilities of BDA are often mistaken for smartness. However, the integration of these analytic technologies into adaptive decision models is necessary to create a smart DSS. In particular, the engagement decisions of actors in a service ecosystem are the locus of smartness in a service. These decisions are dynamic, stochastic and of high dimensionality. Approximate dynamic programming and heuristics are necessary.

## ■ SC26

North Bldg 132A

**Undergraduate Operations Research Prize I**

Emerging Topic: Undergraduate Operations Research Prize

Emerging Topic Session

Chair: Jennifer A. Pazour, Rensselaer Polytechnic Institute, 110 8th Street, CII 5217, Troy, NY, 12180, United States

**1 - Numerical Analysis of the Knowledge Gradient for Locally Quadratic Functions in Multidimensional Learning Settings**

Michael Li, Princeton University, Princeton, NJ, United States, Warren Powell

This paper studies the knowledge gradient for locally quadratic functions (KGLQ), a new policy for optimizing smooth, expensive functions. By capturing structural bias through a tunable parameter, KGLQ encourages more strategic behavior than previous policies. KGLQ is applied to parametric functions, newsvendor functions, and energy arbitrage. Numerical results show KGLQ outperforms its predecessors. However, the optimal tunable parameter values are problem dependent and vary across dimensions.

**2 - Centers for Disease Control and Prevention as a Strategic Agent in the Pediatric Vaccine Market: An Analytical Approach**

Kayla Cummings, Massachusetts Institute of Technology, Cambridge, MA, United States, Banafsheh Behzad, Susan Martonosi

The CDC's significant patronage of pediatric vaccines affords them leverage in preventing monopolies via public sector price negotiation. Our optimization model ensures adequate vaccination levels and manufacturers' success at minimum government cost. We find that dissimilar products advantageously segment markets with asymmetric manufacturers. Furthermore, markets are at lower risk when high-capacity manufacturers have low R&D costs, especially in cases of high demand and asymmetry. A shift from annual contracts to ongoing negotiations would give the CDC more control over market viability.

**3 - Multi-Period Lot Sizing with Supplier Selection: Structural Results, Complexity and Algorithms**

Meichun Lin, Shanghai Jiao Tong University, Shanghai, China, Woonghee Tim Huh, Meichun Lin

We consider a multi-period lot-sizing problem with multiple products and suppliers. We aim to determine the order quantity to minimize the total cost of product purchase and inventory holding under deterministic time-varying demand. We show the intractability of the general problem, analyze structural properties for three polynomial-time solvable cases and propose dynamic programming algorithms. We also develop a heuristic for the general problem and computationally show that it works well.

## ■ SC27

North Bldg 132B

**Moving Online: How Exactly to Repackage a Face to Face Class into an Awesome Online Experience**

Sponsored: Education (INFORMED)

Sponsored Session

Chair: Carrie Beam, University of Arkansas, Walnut Creek, CA, 94596, United States

**1 - Moving Online: How Exactly to Repackage a Face to Face Class into an Awesome Online Experience**

Carrie Beam, University of Arkansas, Walnut Creek, CA, 94596, United States

"I've taught in the classroom for 30 years, and now my dean is pressuring me to move my class online. Where to start?" "I'm the dean they are all complaining about. What management techniques do we need so our faculty are able to happily move online?" Here's a practical roadmap for moving face-to-face classes online. Live examples of online classes in Operations Management, Analytics,



Lean Six Sigma, Decision Models, and Risk Management will show how to proctor online exams, grade handwritten homework, automatically grade custom assignments, and manage the online process.

## ■ SC28

North Bldg 221A

### **Railway Applications Section Problem Solving Competition**

Sponsored: Railway Applications

Sponsored Session

Chair: Michael F. Gorman, University of Dayton, Dayton, OH, 45469, United States

#### **1 - Railway Applications Section Problem Solving Competition**

Michael F. Gorman, University of Dayton, 300 College Park, Dayton, OH, 45469, United States

This session is reserved for the finalists of the RAS Problem Solving Competition: "Train Delay Forecasting". The presenters and their abstracts will be determined by the Judging Committee by early October. More information about the Competition is available at <http://connect.informs.org/railway-applications/awards/problem-solving-competition>.

## ■ SC29

North Bldg 221B

### **Cooperative Traffic**

Sponsored: TSL/Urban Transportation

Sponsored Session

Chair: Daisik Nam, University of California, 2132 Verano Place, Irvine, CA, 92617, United States

#### **1 - Nash Equilibrium with User-Focused Incentives for Envy-minimized**

Daisik Nam, University of California, 2132 Verano Place, Irvine, CA, 92617, United States

This research models an incentivized and interconnected smart route guidance system. The system provides the users with system optimum routes, which distributes travel demands over space and time but induces travel time imbalances and user envy. To compensate for this, optimum incentives are allocated, that attempt to minimize the envy of participants.

#### **2 - Economic Mechanisms for Cooperative Vehicle Platooning**

Xiaotong Sun, University of Michigan, Department of Civil and Environmental Engineering, Ann Arbor, MI, 48109, United States, Yafeng Yin

A vehicle platoon is a set of vehicles driving together with minimum headways, enabled by, e.g., cooperative adaptive cruise control. Benefits of vehicle platooning include energy cost savings, reduced emissions, and others. Since these benefits are not distributed evenly among vehicles in a platoon, some drivers or owners will not be willing to join or stay in a platoon even if they are advised to do so. This study investigates economic mechanisms that fairly allocate the platoon benefits to facilitate vehicles from different owners to form and maintain desired platoons.

#### **3 - Decentralized Cooperative Control for a Mixed Flow Traffic Platoon**

Yujie Li, Purdue University, West Lafayette, IN, United States

This study develops a cooperative control strategy for a platoon with human-driven vehicles (HDVs) and connected and autonomous vehicles (CAVs) on a straight highway to improve the stability of the whole platoon. Specifically, a novel car-following model for HDVs is established to describe the interactions when a HDV follows a CAV. A cooperative decentralized controller is proposed to generate the control inputs of CAVs by considering the interactions between HDVs and CAVs and the performance of the mixed flow platoon. Numerical simulations are used to investigate the performance of the proposed methodology.

#### **4 - Cooperative Adaptive Cruise Control for a Platoon of Connected and Autonomous Vehicles (CAVs) Considering Dynamic Information Flow Topology**

Anye Zhou, Purdue University, West Lafayette, IN, United States

This study seeks to establish a cooperative adaptive cruise control design that considers a dynamic information flow topology for CAV platoons. This mechanism aims to improve the control performance considerably under an unreliable vehicle-to-vehicle communication network. An adaptive Proportional-Derivative (PD) controller under a two-predecessor-following information flow topology is proposed to reduce the negative effects when communication failures occur. The PD controller parameters are determined to ensure the head-to-tail string stability of the CAV platoon.

## ■ SC30

North Bldg 221C

### **Innovations in Facility Logistics – Technology and Models**

Sponsored: TSL/Facility Logistics

Sponsored Session

Chair: Debjit Roy, Indian Institute of Management, Ahmedabad, 560078, India

#### **1 - Dynamic Batch Picking for Order Picking in Warehouses**

Jelmer Pier van der Gaast, University of Groningen, Nettelbosje 2, Groningen, 9747 AE, Netherlands, Bolor Jargalsaikhan, K.J. Roodbergen

Dynamic batch picking is characterized by combining product demand from multiple customer orders into one pick tour where new orders arrive continuously. Using modern order picking aids, updated pick instructions can be included in the current pick tours which allows pickers to be re-routed to pick for new orders even when they already started a pick tour. We develop a mathematical model for dynamic batch picking that minimizes the order throughput time of an incoming order. The model can be quickly re-optimized in case of a new order arrival and used to determine new updated pick tours. This allows for short order throughput times and ensures that companies can set their cut-off times as late as possible.

#### **2 - The Effects of Hurricanes on Port Operations**

Amir Gharehgozli, David Nazarian College of Business and Economics, Northridge, CA, United States, Dylan Folkman

This paper studies the long-lasting effects of hurricanes on port operations. It focuses on the recent effect of hurricane Harvey on the Port of Houston. Hurricane Harvey pushed a large amount of sediment into the Houston Ship Channel, decreasing the depth of the port. As a result, larger vessels need to de-ballast the water from the ballast tanks in order to reduce their draft and enter the port. Arena simulation software is used to simulate the operations at the two main container terminals in the port. Two simulations are created to model the port and its efficiency before Harvey versus after Harvey. The results show a decrease of total revenue and an increase in average waiting time.

#### **3 - Manual Order Picking in a Warehouse**

Ivo Adan, Eindhoven University of Technology, Den Dolech 2, Eindhoven, 5600 MB, Netherlands, Lacy Greening, Rob Broekmeulen, Stijn De Vuyst

We consider manual order-picking in a rectangular warehouse consisting of multiple parallel aisles. The routing heuristic of the picker is the mid-point strategy. We determine mean and variance of the travel time and also evaluate the performance of batching strategies.

#### **4 - Stochastic Models for Comparing Technology Alternatives at Automated Container Terminals**

Govind Lal Kumawat, Indian Institute of Management Ahmedabad, New Campus, Dorm 29 Room 12, Ahmedabad, 380015, India, Debjit Roy

We address a technology selection problem that arises in the development phase of automated container terminals. We compare various technology alternatives for quay cranes and transport vehicles based on the throughput time using semi-open queueing networks. Moreover, we propose a solution method for semi-open queueing networks with two-phase servers and blocking.

#### **5 - Workforce Scheduling with Order Picking Assignments in Distribution Facilities**

Arpan Rijal, Erasmus University, Postbus 1738, Rotterdam, 3062PA, Netherlands, Marco Bijvank, Asvin Goel, René de Koster

Manual order picking operations at several distribution centers operate with temporal restrictions on the completion times of orders in the form of hard earliness or lateness constraints. The problem is further complicated by multiple shift start and end times, mandatory breaks, and flexible workforce. As a result, the sequence of assignment of orders to order pickers is non-trivial. In this work, we present several formulations of the problem and exact and matheuristic solution approaches for it. Preliminary results show that definition of shifts and break requirements have significant impact on operational costs.

## ■ SC31

North Bldg 222A

**Modeling and Evaluation of Transportation Infrastructure with New Technologies**

Sponsored: TSL/Intelligent Transportation Systems (ITS)

Sponsored Session

Chair: Michael Levin, University of Texas, Austin, TX, 78731, United States

**1 - A Scalable and Real-time Approach for Optimal Signal Control in a Semi-connected Vehicle Environment**

Ali Hajbabaie, Washington State University, 405 Spokane St, Pullman, WA, 99164, United States, S. M. A. Bin Al Islam, Husain Aziz

This research presents an algorithm to incorporate point detector data with shared information of connected vehicles (CV) for real-time optimal signal control with various CV market penetration rates. Besides, a transit signal priority (TSP) based mixed-integer linear program (MILP) is formulated to accommodate multiple modes of vehicles while considering effective coordination between neighboring intersections. The results indicated significant improvement in network performance under various CV penetrations rates compared to the state-of-practice TSP using microscopic traffic simulation.

**2 - Performance Evaluation of Connected and Cooperative Driving: Queueing Theoretic Approach and Case Study**

Mohammad Motie, University of Southern California, Los Angeles, CA, 90089, United States, Ketan Savla

We develop a queueing theoretic framework for performance analysis, in terms of throughput and travel time, for freeway systems under connected vehicles and cooperative driving. In particular, we derive theoretical bounds under well-studied car-following models, and compare with microscopic simulations and the NGSIM dataset.

**3 - A Machine Learning Based Signal Control Algorithm with Energy Minimization Objective**

S. M. A. Bin Al Islam, Graduate Research Assistant, Washington State University, 242, Sloan Hall, NE Spokane St, Pullman, WA, 37830, United States, Husain Aziz, Ali Hajbabaie

This paper presents a distributed agent-based reinforcement learning (RL) technique to minimize energy consumption from signalized intersections while considering effective coordination in decision making processes among adjacent intersections. Besides, we propose a mobility-energy objective to provide a balanced reward function in RL based signal control algorithm. The algorithm is implemented in a calibrated NG-SIM network within a traffic microsimulator-PTV VISSIM and compared with current signal settings of the network and hypothetical optimal solutions.

**4 - Network Traffic Control for Autonomous and Legacy Vehicles**

Michael W. Levin, University of Minnesota, 500 Pillsbury Dr. SE, Minneapolis, MN, United States, David Rey

Autonomous vehicles are expected to help in improving network capacity and mitigate congestion episodes. Yet, there is a lack of traffic control models capable of managing both legacy and autonomous vehicles. We address this gap by optimizing traffic signal control at the intersection level considering mixed traffic flow. We then embed this formulation into a network-level traffic control model wherein link queue evolution dynamics are stochastic. We propose a distributed network traffic control policy inspired by back-pressure algorithms to maximize network throughput and we prove stability.

## ■ SC32

North Bldg 222B

**Joint Session TSL/ICS: Approximate Dynamic Programming and Reinforcement Learning for Routing III**

Sponsored: TSL/Freight Transportation &amp; Logistics

Sponsored Session

Chair: Justin Goodson, Saint Louis University, St. Louis, MO, 63108, United States

**1 - Dynamic Time Window Allocation and Sizing for Service Routing**

Justin Goodson, Saint Louis University, John Cook School of Business, Davis-Shaughnessy Hall, St. Louis, MO, 63108, United States, Marlin Wolf Ulmer, Barrett Thomas

Firms serving customers at their homes face the challenge of assigning time windows small enough to respect busy schedules, but large enough to provide adequate service. At the time of a request, the firm must provide a window within which service will begin. Accurately estimating arrival times to customers is difficult because requests arrive randomly and must be assigned to employees

in real time without knowing when and where future requests will occur. We show dynamic strategies to set time windows as a function of arrival time variance perform significantly better than static policies.

**2 - Ship Routing Problems: Closing the Optimality Gap**

Thibaut Vidal, PUC-Rio, Departamento de Informatica, Rua Marques de Sao Vicente, 225, Rio de Janeiro, 22453-900, Brazil, Gabriel Homs, Rafael Martinelli, Kjetil Fagerholt

Hemmati et al. (2014) recently introduced real ship routing instances which pose considerable challenges for solution methods. To face this situation, we introduce a hybrid GA and a branch-price-and-cut-based algorithm. Our GA combines a set-partitioning with problem-tailored variation operators to optimize all decision subsets. Our BCP generates elementary routes and relies on strong branching, sophisticated preprocessing and correction techniques for the delivery triangle inequality, route enumeration and subset-row cuts. As visible in our experiment, the BCP solves to optimality all of the 240 available instances, and the GA finds solutions which are near optimal in a few minutes.

**3 - Dynamic Car-passenger Matching for on Demand Mobility Services**

Marvin Erdmann, University of the German Federal Armed Forces, Munich, Werner-Heisenberg-Weg 39, Neubiberg, 85577, Germany Marvin Erdmann, BMW, Parkring 19, Garching, 85748, Germany

Today's challenges of urban traffic - congestion, lack of space, air pollution, etc. - can be met by On Demand Mobility, a concept that would lead to an enhanced use of shared mobility services to utilize the vehicles more efficiently. This trend becomes even more obvious with the future development of autonomous driving vehicles. To avoid a decline of flexibility and convenience for the customers the fleet management function will match the requests and the vehicles in order to quickly find a reliable and time efficient solution for the whole system. My work's focus is the realization of a Tabu Search Metaheuristic to compute near-to-optimal solutions for this NP hard problem.

## ■ SC33

North Bldg 222C

**Strategic Decision Making for Emergency Medical Services**

Sponsored: Transportation Science &amp; Logistics

Sponsored Session

Chair: Lavanya Marla, U. of Illinois at Urbana-Champaign, Urbana, IL, 61801, United States

**1 - Competitive Coverage with Two EMSs**

Peter McGlaughlin, University of Illinois-Urbana Champaign, Urbana, IL, United States

We study a stochastic game in which two service providers (the players) compete for customers. Player maintain a base at one end point of the service area, a line of length 1, and selects a coverage range  $0 < x < 1$ . Customers arrive by the Poisson process at a random position, and request service from all providers whose range overlaps their position. If a player has an available server, it is dispatched to the customer's location. Only the first player to arrive receives a reward. Players aim to maximize utility, the time average number of customers served, by adjusting coverage range  $x$ . When the players have one server, we show that there always exists a symmetric pure strategy Nash equilibrium.

**2 - Evaluating Capacity Planning Methods for Erlang-B Systems: Application to Emergency Medical Services**

Mohammad Delasay, Stony Brook University, Stony Brook, NY, United States, Armann Ingolfsson, Amir Rastpour

We evaluate capacity planning methods in Erlang-B service systems with continuous random cyclic demands. Emergency medical services is an example of such systems. We use numerical techniques to evaluate the accuracy of methods that rely on independent period-by-period steady state distributions. We investigate how the accuracy of such approximations depends multiple factors, including the average service rate and the shape of the service time distribution.

**3 - Capacity Rationing and Ambulance Diversion in Emergency Departments**

Tianshu Lu, University of Toronto-Rotman School of Management, 105 St George Street, Toronto, ON, M5S 3E6, Canada, Jianfu Wang, Opher Baron

Capacity rationing and ambulance diversion are two important practices in emergency department (ED) management. We model these practices as a two classes non-preemptive priority  $M/M/c+M$  queue where high- and low-priority customers correspond to acute and non-acute patients, respectively. We model capacity rationing by reserving  $k$  servers to high priority customers, and ambulance diversion by blocking high priority customers from entering the system when the total number of patients is high. We give the first exact results for a multi-server queue with non-preemptive priorities. Numerical results provide insights on the control of capacity rationing and ambulance diversion in EDs.

#### 4 - Emergency Response After Disaster Strikes: Agent-based Transportation Simulation of Ambulances in New Windsor, NY

Matthew Yuan, United States Military Academy, West Point, NY, 10996, United States, Zade J. Koch, Elizabeth Bristow

Ambulance travel time in New Windsor, NY is modeled using the agent-based transportation microsimulation software MATSim. MATSim was used to compare ambulance travel time before and after disruption of critical roadways, simulating the effects of a natural disaster. When 0.6% of network links in New Windsor were restricted to 50% of their maximum speed, ambulance travel time increased by 6.05%. Applying agent-based techniques to emergency response planning is a novel approach which offers network analysts and city planners advantages over traditional transportation modeling approaches.

## ■ SC34

North Bldg 223

### 1:30 - 2:15 Modular Mining Systems/ 2:15 - 3:00 GAMS

Vendor Demo Session

#### 1 - Modular Mining Systems

Abstract not available.

#### 2 - GAMS - An Introduction

Steven P. Dirkse, GAMS Development Corporation, Washington, DC, United States, Lutz Westermann

Get ready to learn the basics of GAMS, i.e. how to develop algebraic models and solve them using state-of-the-art algorithms. In this workshop, the key concepts of GAMS and the fundamentals of the language (e.g. sets, data, variables, equations) will be introduced. The main part will consist of a demonstration, where we build a simple optimization-based decision support application from scratch. We show how GAMS supports an easy growth path to larger and more sophisticated models, promotes speed and reliability during the development phase of optimization models, and provides access to all of the most powerful solver packages. Along the way we will look at some of the data management tools included in the GAMS system and show how to analyze and debug large problems using the various tools available within GAMS. This introduction assumes no familiarity with GAMS. There will be time for questions both during and at the end of this workshop.

## ■ SC35

North Bldg 224A

### Joint Session AAS/TSL-Air: Flight Schedule Optimization under Demand-capacity Imbalances

Sponsored: Aviation Applications

Sponsored Session

Chair: Konstantinos G. Zografos, Lancaster University, Lancaster, LA1 4YX, United Kingdom

Co-Chair: Alexandre Jacquillat, Carnegie Mellon University, Carnegie Mellon University, Pittsburgh, PA, 15213, United States

#### 1 - A Large-scale Neighborhood Search Approach to Airport Slot Allocation

Alexandre Jacquillat, Carnegie Mellon University, Heinz College, 5000 Forbes Avenue, Pittsburgh, PA, 15213, United States, Nuno Ribeiro, Antonio Antunes, Amedeo R. Odoni

The airport slot allocation problem has been the focus of extensive research in recent years; yet, exact methods only yield optimal solutions at airports of up to 100,000 aircraft movements per year. We provide here a novel approach that leverages a recent Priority-based Slot Allocation Model (PSAM), and develops heuristic based on large-scale neighborhood search to solve it at the largest schedule-coordinated airports. Specifically, we propose a constructive heuristic that is shown to provide good solutions in short computational times and an improvement heuristic that converges to the optimal, or near-optimal solution in a few hours. Case study results are shown at Lisbon's airport.

#### 2 - An Integrated Scheduling and Flow Management Approach in Air Transportation Networks

Kai Wang, The Hong Kong Polytechnic University, Hong Kong, Alexandre Jacquillat

Two central air traffic management (ATM) problems are demand management, i.e., strategic scheduling interventions, and air traffic flow management (ATFM), i.e., tactical balancing of aircraft flows. This paper provides an original integrated approach that optimizes network-wide scheduling interventions, while accounting for ATFM dynamics and operating uncertainty. This is formulated as a two-stage stochastic integer program. We develop new exact solution algorithms based on dual integer cuts and neighborhood search, which are shown to provide optimal, or near-optimal solutions in reasonable computational times. Case study results identify opportunities in network demand management.

#### 3 - Decomposition Methods for Solving the Slot Allocation Problem with Flexible Scheduling of Series of Slots

Jamie Fairbrother, Lancaster University, Department of Management Science, Management School, Lancaster, LA1 4YW, United Kingdom, Stephen John Maher, Konstantinos G. Zografos, Kevin D. Glazebrook

We formulate the airport slot scheduling problem as a bi-objective integer linear problem which considers efficiency and fairness objectives and satisfies turn-around and airport capacity constraints. This model allows flexibility for the scheduling of series of slots during the scheduling season. We develop and test Benders' decomposition and column generation algorithms for solving the proposed formulation and report results regarding the computational performance of these.

#### 4 - Accommodating New Flights into the Existing Airline Flight Schedule

Ozge Safak, Department of Industrial Engineering, Ankara, 06800, Turkey, Alper Atamturk, Selim Akturk

We present two novel approaches to alter the flight network to accommodate new flights while maximizing airline's profit. The key feature is to adjust the aircraft cruise speed to compensate for the block times of new flights, trading off flying time and fuel burn. We introduce an additional mechanism, namely aircraft swapping, which provides a greater flexibility in reducing the fuel cost. We propose strong mixed integer conic quadratic (MICQ) formulations to handle the nonlinear fuel burn function. This MICQ formulation together with the McCormick inequalities enables the solution of large-scale instances from a major U.S. airline within reasonable compute times. TUBITAK Grant 116M542, 2214

## ■ SC36

North Bldg 224B

### Aviation: A Whole New World?

Sponsored: Aviation Applications

Sponsored Session

Chair: Arnold I. Barnett, Massachusetts Institute of Technology, Cambridge, MA, 02139-9910, United States

#### 1 - Aviation Safety: A Solved Problem?

Arnold I. Barnett, Massachusetts Institute of Technology, 100 Main Street, E62-568, Mit, Cambridge, MA, 02139-9910, United States

In 2017, roughly four billion passengers worldwide embarked on air journeys on scheduled flights, only ten of whom were killed. Viewed in isolation, this outcome suggests that events that produce aviation deaths are on the verge of extinction. But is 2017 a temporary fluctuation around a general trend that has persisted for the last fifty years? We explore the issue with aviation-fatality data.

#### 2 - A Recheck on TSA PreCheck: Aviation Security in 2040

Sheldon H. Jacobson, University of Illinois, Dept of Computer Science, 201 N. Goodwin Avenue MC258, Urbana, IL, 61801-2302, United States

TSA Precheck is the poster child for risk-based security, the strategy that aligns security resources with risk. This presentation discusses how risk-based security in general, and TSA PreCheck in particular, can be enhanced to make the air system for secure for all travelers over the next two decades.

#### 3 - Smart Markets for Smart Aircraft

Raja Sengupta, University of California-Berkeley, Berkeley, CA, United States, Mark Hansen

Advances in materials, cyber- intelligence, and manufacturing have spawned a renaissance in Aerospace Engineering. Civil Aviation now faces unprecedented growth opportunities, if a vastly richer mix of aircraft, products of the aerospace renaissance, can be admitted into the airspace in sufficient numbers. Our research is about realizing this opportunity. The key is to bring new aircraft to market in times that fit venture investment cycles. Our research targets a permissive airspace system in both tropo- and stratosphere, which is safe and efficient for the incumbent aircraft, but yet fast-to-market for the innovations to come.

#### 4 - Competition and Collaboration for Airport Capacity Allocation: Review and Recent Findings

Vikrant Vaze, Dartmouth College, 14 Engineering Drive, Murdough Center, Hanover, NH, 03755, United States

Commercial airlines, which are the main users of airport capacity, share a complicated relationship with each other. On one hand, they compete with each other for passenger share and fare revenues. On the other hand, effective coordination, communication and collaboration between them are essential for efficient utilization of airport resources. This talk focuses on developing, optimizing and evaluating mechanisms for airport capacity allocation while incorporating airline preferences. We address challenges associated with long-term strategic planning as well as short-term tactical decision-making. We briefly mention a broader set of applications of the ideas developed in this research.



## ■ SC37

North Bldg 225A

**Data, Services, and Queues**

Sponsored: Applied Probability

Sponsored Session

Chair: Rouba Ibrahim, University College London, London, WC1E 6BT, United Kingdom

**1 - Linking Delay Announcements, Loss Aversion, and Abandonment: A Behavioral Perspective**Eric M. Webb, Assistant Professor, Lindner College of Business,  
University of Cincinnati, Cincinnati, OH, United States,  
Qiuping Yu, Kurt M. Bretthauer

Using field data from a call center, we study the behavioral determinants of customers' queue abandonment decisions in the presence of delay announcements. Customers exhibit loss aversion with respect to time losses in queue, becoming much more likely to abandon if forced to wait longer than expected. We test the robustness of loss aversion across multiple announcements, customer class types, and functional forms of loss aversion. In addition, we study the effect of the queue experience on the time in service for those customers who do not abandon.

**2 - The Impact of Economic Drivers on Gig Economy Workers: Structural Estimation Approach**Gad Allon, University of Pennsylvania, 3730 Walnut Street,  
Philadelphia, PA, 19104, United States, Park Sinchaisri,  
Maxime Cohen

While gig economy firms benefit from increased labor flexibility, ensuring that their services appeal to independent providers poses a great challenge in planning and committing to a service capacity. We study how on-demand workers make labor decisions: when to work and for how long? Our project is in collaboration with a ride-hailing company with the goal to not only improve the way of predicting the number of active drivers, but also understand how to better recruit them, as a way to match supply and demand. We use a structural estimation approach to study how drivers respond to different incentives.

**3 - Last Place Aversion in Queues**Ryan Buell, Harvard Business School, Morgan Hall 429, Boston,  
MA, 02163, United States

This paper investigates whether people exhibit last place aversion in queues and its implications for their experiences and behaviors in service environments. A combination of field and lab evidence reveals that waiting in last place diminishes wait satisfaction while doubling the probability of switching and quadrupling the probability of abandoning queues. This behavior is partially explained by the inability to make a downward social comparison; namely, when no one is behind a queuing individual, that person is less certain that continuing to wait is worthwhile. The results also demonstrate how queue transparency is an effective design lever for reducing last place aversion in queues.

**4 - History Based Priority Policies**Brett Hathaway, UNC Chapel Hill, 1800 Baity Hill Drive #310,  
Chapel Hill, NC, 27514, United States, Seyed Morteza Emadi,  
Vinayak V. Deshpande

We study the behavior of callers in a banking call center. Using a latent class decision model, we estimate that callers differ in their abandonment and redialing behavior based on intrinsic heterogeneity in their behavior and their unique histories of waiting times and decisions with the call center. We introduce a class of policies where callers are prioritized based on our model's predictions of their behavior, which depend on their history. We find that under history-based policies this call center could reduce average waiting times by 10 percent while increasing sales opportunities by 3 percent.

## ■ SC38

North Bldg 225B

**APS Session Reed**

Sponsored: Applied Probability

Sponsored Session

Chair: Joshua Reed, New York University, New York, NY, 10012, United States

**1 - A Dirichlet Process Characterization of RBM in a Wedge**Josh Reed, NYU, New York, NY, United States, Peter Lakner,  
Bert Zwart

We prove that in the case of  $1 < \alpha < 2$ , RBM in a wedge is a Dirichlet process. Specifically, its unique Doob-Meyer type decomposition is given by  $Z = X + Y$ , where  $X$  is a two-dimensional Brownian motion and  $Y$  is a continuous process of zero energy. Furthermore, we show that for  $p > \alpha$ , the strong  $p$ -variation of the sample paths of  $Y$  is finite on compact intervals, and, for  $0 < p \leq \alpha$ , the strong  $p$ -variation of  $Y$  is infinite on  $[0, T]$  whenever  $Z$  has been started from the origin. We also show that  $(Z, Y)$  satisfies the extended Skorokhod problem for  $X$ .

**2 - Asymptotic Analysis of Multiclass Queues with Random Order of Service**Mohammadreza Aghajani, University of California San Diego,  
9500 Gilman Drive # 0112, La Jolla, CA, 92093, United States

Queueing models under Random order of Service (ROS) policy have been used to study molecular interactions of intracellular components in biology. However, these models often assume exponential distributions for processing and patience times, which is not realistic. We study a multiclass queueing model under ROS with reneging and generally distributed processing and patience times. We use measure-valued processes to describe the dynamic evolution of the network, and establish a fluid and diffusion approximations for this representation. These limits are characterized by deterministic and stochastic non-linear Partial Differential Equations, whose analysis requires new techniques.

**3 - Ergodic Control of a Class of Jump Diffusions with Finite Levy Measures and Rough Kernels**Yi Zheng, The Pennsylvania State University, State College, PA,  
United States, Ari Arapostathis, Luis Caffarelli, Guodong Pang

We study the ergodic control problem for a class of jump diffusions in  $\mathbb{R}^d$ , which are controlled through the drift with bounded controls. The Levy measure is finite, but has no particular structure. Unstable behavior is 'discouraged' by the running cost which satisfies a mild coercive hypothesis. We first study the problem as an optimization problem on the space of infinitesimal ergodic occupation measures, and derive the Hamilton-Jacobi-Bellman equation, including verification of optimality results, using only analytical arguments. We also examine the regularity of invariant measures. Then, we address the jump diffusion model, and obtain a complete characterization of optimality.

**4 - Existence and Uniqueness of Obliquely Reflecting Diffusions in Cusps**Cristina Costantini, University of Chieti-Pescara, Pescara, Italy,  
Thomas G. Kurtz

In a 2009 paper, Kang, Kelly, Lee and Williams proposed a diffusion approximation for the workload process in a model for a network operating under a weighted a-fair bandwidth sharing policy. For  $\alpha < 1$  the diffusion approximation cannot be proved because the diffusion state space presents cusp-like singularities and suitable uniqueness results are not available. We prove weak existence and uniqueness for a semimartingale reflecting diffusion in a 2-dimensional cusp, with a varying oblique direction of reflection on each side, under the only assumption that there exists a vector that has positive scalar product with the common tangent to the two sides and with the two directions of reflection at the tip.

## ■ SC39

North Bldg 226A

**Machine Learning and Applied Probability**

Sponsored: Applied Probability

Sponsored Session

Chair: Daniel Russo, Columbia University, New York, NY,

**1 - Optimal Hardness of Questions in Static and Interactive Exams**Sandeep Juneja, Tata Institute of Fundamental Research,  
Homi Bhabha Road, Mumbai, Maharashtra, 400005, India,  
Achal Bassamboo, Assaf Zeevi

We consider the problem of designing a perfect exam, one that minimizes the mis-classification or mis-grading probability. We consider both static as well as interactive exams. Student's probability of success in a question is modelled as an increasing function of her ability and decreasing function of question hardness. Ability itself may be a random variable. We use pure exploration Bandit framework to develop sample complexity lower bounds. We also develop algorithms whose computational effort matches the dominant term in the lower bounds.

**2 - Distributional Robustness in Machine Learning: Statistical and Computational Guarantees**Hongseok Namkoong, Stanford University, Stanford, CA,  
United States

We study distributionally robust approaches to statistical learning, and provide finite-sample and asymptotic results characterizing the theoretical performance of the estimator. We also develop efficient solution methods for such approaches, and empirically verify that distributional robustness is a valuable approach in a number of machine learning applications where reliability is a key concern. Our approach learns the tails of the distribution, hedges against potential covariate shifts, promotes fairness across demographics, and provides robustness against adversarial attacks.

**3 - Distributionally Robust Optimal Bidding in First-Price Auctions**

Jose Blanchet, Stanford University, Stanford, CA, United States

Until recently, second price auctions overwhelmingly dominated the market making mechanics in online advertising, but there is a clear trend in which online advertising exchanges are using first-price auctions (and other types of mechanisms) for market making. Optimal bidding in these types of auctions requires highly detailed knowledge on the bidder's competitive landscape, making it extremely challenging for Demand Side Platforms (or DSPs) to manage strong campaigns on behalf of the advertisers. So, distributionally robust optimization (DRO) is particularly well-suited in this setting. We introduce a framework based on DRO which is simple, interpretable and provides reasonable bidding policies which are well-suited for DSP use.

**4 - Sample-based Optimal Pricing**

Amine Allouah, Columbia University, New York, NY, 10027, United States, Omar Besbes

We study the problem of optimal pricing to sell one indivisible good to a buyer, when facing limited information about the willingness-to-pay distribution. In particular, we characterize optimal performance based on a single sample.

**SC40**

North Bldg 226B

**Stochastic Models and Control**

Sponsored: Applied Probability

Sponsored Session

Chair: Rami Atar, Technion, Technion, Haifa, 32000, Israel

**1 - Some Notions of Minimality for Resource Sharing Networks and their Fluid Models**

Lukasz Kruk, Maria Curie-Skłodowska University, Lublin, Poland

We consider real-time stochastic resource sharing networks with soft customer deadlines and arbitrary topology. For such systems, we introduce several notions of pathwise minimality and we discuss their relations to the Earliest-Deadline-First service discipline. We also mention some counterparts of these minimality concepts for fluid models of resource sharing networks.

**2 - Large Deviations for M/M/1 Queue with Abandonment and Long-time Analysis**

Ruoyu Wu, University of Michigan, Ann Arbor, MI, United States, Rami Atar, Amarjit Budhiraja, Paul Dupuis

We consider M/M/1 queue with abandonment according to exponential clocks. A large deviation principle is established for the queue length and total abandonment processes. We study the exponential decaying rate, and its long-time asymptotics, of the probability that there are more abandonment than the law of large numbers limit. Discussions on analyzing related risk sensitive control problems and large deviation bounds of G/G/1 queue with abandonment, using variational formula of the Renyi divergence, are also provided.

**3 - A Fluid Limit for an Overloaded Multi-class Many-server Queue with General Reneging Distribution**

Amy R. Ward, University of Southern California, Marshall School of Business, Bridge Hall BRI 401H, Los Angeles, CA, 90089-0809, United States, Amber L. Puha

We study scheduling in a many server queue with general reneging distribution ( $G/G/N+G$ ) and multiple customer classes. Motivated by the goal to formulate and analyze a fluid control problem, we specify a class of admissible control policies (rules for determining when to serve a given customer class), formulate a fluid model, and characterize the invariant states. Static priority policies do not capture the entire spectrum of invariant states, and so we introduce a set of control policies, called Random Buffer Selection (RBS) that do. We prove that a suitably rescaled state descriptor for the queue operating under specified RBS policy converges to the unique fluid model solution for that RBS policy.

**4 - Subgeometric Ergodicity of Levy Driven SDEs Arising from Multiclass Many Server Queues**

Ari Arapostathis, University of Texas at Austin, Austin, TX, USA, Guodong Pang, Nikola Sandric

We study a class of multidimensional piecewise Ornstein-Uhlenbeck processes with jumps, which contains limiting diffusions arising in multiclass many-server queues subject to heavy-tailed arrivals and/or asymptotically negligible service interruptions in the Halfin-Whitt regime as special cases. We identify conditions on the parameters in the drift, the Levy measure and/or covariance function which result in subexponential and/or exponential ergodicity. We show that these assumptions are sharp, and we identify some key necessary conditions for the process to be ergodic. In addition, we show that for the queueing models described above with no abandonment, the rate of convergence is polynomial, and we provide a sharp quantitative characterization of this rate via matching upper and lower bounds.

**SC41**

North Bldg 226C

**Preferences in Project Evaluation and Selection**

Sponsored: Decision Analysis

Sponsored Session

Chair: Enrico Diecidue, INSEAD, Fontainebleau Cedex, 77305, France

**1 - Net Present Value Analysis of Projects under Expected Utility**

Manel Baucells, University of Virginia, Darden School of Business, 100 Darden Boulevard, Charlottesville, VA, 22903, United States, Samuel Bodily

The traditional decision-analytic approach to evaluate projects is to calculate the expected utility of initial capital plus net present value. The choice of discount rate, and the convergence with the traditional finance approach, have always been a question. Our goal is to fill this gap. Under assumptions compatible with the CAPM model, we find a convenient rate to discount portfolio capital (treasuries, stocks, and the project). We also cater to practitioners, who discount the cash flows of the project, and ignore the market uncertainty. For them, we propose an adjusted discount rate that correctly compensate for the omission.

**2 - Probability Dominance**

Enrico Diecidue, INSEAD, Boulevard De Constance, Fontainebleau Cedex, 77305, France

We test whether a simple heuristic of maximizing the probability of being ahead, probability dominance (PD), affects decisions under risk. We set up head-to-head situations where all preferences of a given class (expected utility, prospect theory, or regret theory) are for one alternative yet PD favors the other. Our experiments reveal that: the majority of choices are aligned with PD in contradiction to any form of expected utility maximization, prospect theory preferences, and regret theory. We conclude that probability dominance affects choices, and should therefore be incorporated into decision making models. We quantify a lower bound on its weight in the decision-making process.

**3 - Optimal Switching Between Projects with Different Profitability and Uncertainty Characteristics**

Tord Olsen, PhD Student, Norwegian University of Science and Technology, Alfred getz vei 3, Trondheim, 7491, Norway, Verena Hagspiel

We consider a firm with an investment opportunity to introduce a new product, where the profit is modelled as a geometric Brownian motion, and the drift and volatility of the underlying process changes after investment. We find that under the assumption of a concave profit function, the conventional insight of investment under uncertainty, that an increase in uncertainty delays investments, might not hold if the characteristics of the stochastic process changes after the investment. Further, we show that a case with a boost in the profit function under constant parameters of the stochastic process can be transformed to a case of constant profit function with changes to the underlying process.

**4 - Decomposition of Sensitivity Analysis for Problems with Correlated Inputs**

Warren Joseph Hahn, The University of Texas at Austin, McCombs School of Business, 217 Grant Cannon Lane, Austin, TX, 78738, United States, Tianyang Wang, James Dyer

The state of the art for sensitivity analysis of decision making problems with dependencies between input variables are fully probabilistic techniques which simultaneously vary all input variables. However, much of the intuition desired from sensitivity analysis is not provided with these methods because they do not isolate the marginal effects of the individual variables. In this paper, we present an approach that provides results that are identical to those from a fully-probabilistic sensitivity analysis, but which also decomposes the sensitivity to each individual input variable into its marginal dependence-constrained sensitivity and its sensitivity due to dependence with other inputs.

## ■ SC42

North Bldg 227A

### Agent Based Simulation in Healthcare

Sponsored: Simulation

Sponsored Session

Chair: Chao Meng, Valdosta State University

#### 1 - Data Analytics Integrated Simulation for Older Adults Healthcare Utilization Modeling and Evaluation under Multi-type Settings

Xuxue Sun, University of South Florida, 4202 E. Fowler Ave., ENB 118, Tampa, FL, 33620, United States, Chao Meng, Nan Kong, Hongdao Meng, Kathryn Hyer, Mingyang Li

To meet the ever-increasing healthcare demand of America's older adults with the limited and costly healthcare resources, there is a pressing need to investigate how a heterogeneous population of older adults will influence the utilization of different healthcare settings, such as acute care and long-term care facilities. In this work, advanced Bayesian data analytics is integrated with the simulation techniques to jointly model and evaluate both hospital and nursing home healthcare utilization. Real case studies based on Florida's Medicare and Medicaid claims data are studied to demonstrate the effectiveness of the proposed framework.

#### 2 - Multi-agent Based Hybrid Adaptive Training System for Functional Endoscopic Sinus Surgery (FESS)

Saurabh Jain, University of Arizona, Tucson, AZ, 85719, United States, Seunghan Lee, Samuel Barber, Eugene Chang, Young-Jun Son

Multi-Agent Simulation has been widely adopted for training programs. In Otolaryngology, FESS benefits from simulation due to steep learning curves to decrease operative risks and time. We propose a multi-agent task planning framework with adaptive feedback based on real-time evaluation of trainee's surgical proficiency in a virtual environment. This system encapsulates cost-effectiveness, high-fidelity and optimal computation guided by real-time responses.

#### 3 - Hospital Supply Chain Network Design using Agent Based Simulation

Sojung Kim, Texas A&M University-Commerce, P.O. Box 3011, Engineering & Technology, Commerce, TX, 75429-3011, United States, Karli Thornton

This study aims at developing a hospital supply chain using agent-based simulation (ABS) to minimize the total operational cost. Since ABS includes multiple agents making decisions based on their perception processes, it can accurately model a realistic healthcare supply chain environment. Three agents such as consumers, distribution centers, and hospitals are developed under AnyLogic® ABS software with a healthcare supply chain data in Montana, USA. In addition, OptQuest® in AnyLogic is used as an optimization engine to find the appropriate locations of distribution centers in a hospital supply chain network.

## ■ SC43

North Bldg 227B

### Advances in Integrated Assessment Modeling

Emerging Topic: Energy and Climate

Emerging Topic Session

Chair: Yongyang Cai, Ohio State University, OH, United States

#### 1 - Using Integrated Models to Value the Use of Bulk Energy Storage for Reducing CO2 Emissions from Regional Electricity Systems

Jeffrey M. Bielicki, Ohio State University, Hitchcock Hall, 2070 Neil Avenue, Columbus, OH, 43210, United States, Jonathan D. Ogland-Hand, Yaoping Wang, Benjamin M. Adams, Thomas A. Buscheck, Martin O. Saar

Bulk energy storage (BES) can reduce CO2 emissions by increasing the utilization of variable wind and solar electricity capacity. BES could thus have value to reducing system-wide CO2 emissions. We integrated process-level modeling with a systems-level optimization model to estimate this value for CO2-Geothermal Bulk Energy Storage, Compressed Air Energy Storage, and Pumped Hydro Energy Storage. Our results suggest that the value of BES to reducing CO2 emissions can exceed the operating costs of BES, but BES deployment does not always reduce CO2 emissions: the dispatch order, the net load, and the BES technology all influence how BES changes system-wide CO2 emissions.

#### 2 - DRFEWS: A Dynamic Regional Integrated Framework of Food, Energy and Water Systems

Shaohui Tang, The Ohio State University, 2120 Fyffe Rd., Columbus, OH, 43210, United States, Yongyang Cai, Brian Cultice, Yaoping Wang, Jeffrey Bielicki, Randall Alan, Ian Sheldon, Elena Irwin

We build a new integrated Dynamic Regional Food, Energy, Water Systems (DRFEWS) modeling framework that incorporates key economic elements and environmental linkages. The framework represents the regional production of food and energy services that use land, water, energy resources and that depend on farmer behavior and watershed dynamics. It accounts for environmental impacts from regional production and the effects of exogenous changes in uncertain national and global conditions (e.g., trade war, climate change) on the regional FEWS. We apply the model to the Great Lakes region to simulate its regional FEWS dynamics over time.

#### 3 - Climate Policy under Cooperation and Competition between Regions with Spatial Heat Transport

Yongyang Cai, Ohio State University, Columbus, OH, United States, William Brock, Anastasios Xepapadeas, Kenneth Judd

We build a novel stochastic dynamic regional integrated assessment model (IAM) of the climate and economic system including a number of important climate science elements that are missing in most IAMs. These elements are spatial heat transport from the Equator to the Poles, sea level rise, permafrost thaw and tipping points. We study optimal policies under cooperation and various degrees of competition between regions. Our results suggest that when the elements of climate science which are accounted for in this paper are ignored, important policy variables such as the social cost of carbon and adaptation could be seriously biased.

## ■ SC44

North Bldg 227C

### Algorithms for Power Systems

Sponsored: Energy, Natural Res & the Environment/Electricity

Sponsored Session

Chair: Richard Zhang, UC Berkeley, Berkeley, CA, 94709, United States

Co-Chair: Somayeh Sojoudi, University of California, Berkeley, Berkeley, CA, 94703, United States

#### 1 - ARPA-E Grid Optimization Competition

Kory W. Hedman, Program Director, Advanced Research Projects Agency-Energy, Washington, DC, United States

This talk will give background information regarding the Advanced Research Projects Agency-Energy (ARPA-E) and related efforts in the areas of energy systems and operations research. The goal of ARPA-E's Grid Optimization (GO) Competition is to challenge the research and industrial communities to develop transformational and disruptive methods for solving power system optimization problems, including the security-constrained AC optimal power flow (SCOPF), a non-convex optimization problem. More information can be found at: <https://gocompetition.energy.gov/>.

#### 2 - Efficient Computational Methods for Optimal Power Flow, State Estimation and Topology Error Detection

Javad Lavaei, University of California, Berkeley, 4141 Etcheverry Hall, Berkeley, CA, 94720, United States

Power optimization problems are nonlinear and subject to modeling errors. In this talk, we develop efficient mathematical techniques based on both conic optimization and local search algorithms to solve fundamental power operational problems with guarantees. We test our techniques on various real-world systems.

#### 3 - Sparse Semidefinite Programs with Near-linear Time Complexity

Richard Zhang, UC Berkeley, 621 Sutardja Dai Hall, University of California, Berkeley, CA, 94709, United States

Some of the strongest polynomial-time relaxations to NP-hard problems are semidefinite programs (SDPs), but their high solution complexities limits their use. Given that SDP relaxations are often sparse, a technique known as chordal conversion can sometimes reduce complexity substantially. In this paper, we describe a modification of chordal conversion that allows any general-purpose interior-point method to solve a certain class of sparse SDPs with a guaranteed complexity of  $O(n^{1.5})$  time and  $O(n)$  memory. To illustrate the use of this technique, we solve the AC optimal power flow relaxation (ACOPF) on power system models with up to  $n = 13659$  nodes in 5 minutes, using SeDuMi on a standard laptop.

#### 4 - Statistical Analysis of PMU Data

Daniel Bienstock, Columbia University, Dept of IEOR, 342 Mudd, New York, NY, 10027, United States

We describe ongoing work using PMU data obtained through an industrial collaboration, focusing on structural analysis. Another facet of the research involves fast estimation of principal components of covariance matrices (i.e., streaming PCA). This is joint work with Mauro Escobar and Apurv Shukla (Columbia) and Michael Chertkov (LANL).



## ■ SC45

North Bldg 228A

**Environmental and Social Impacts of Power System Expansion Investments**Sponsored: Energy, Natural Res & the Environment/Electricity  
Sponsored Session

Chair: Enzo E. Sauma, Pontificia Universidad Catolica de Chile, Santiago, Chile

**1 - A Mechanism for Allocating Benefits and Costs from Transmission Interconnections under Cooperation: A Case Study of the North Sea Offshore Grid**

Francisco Munoz, PhD, Universidad Adolfo Ibañez, Santiago, Chile, Martin Kristiansen, Shmuel S. Oren, Magnus Korpas

We propose a generic mechanism to allocate these benefits among neighboring countries that are willing to reach a cooperative agreement to support a set of cost-efficient projects. Our mechanism is based on a planning model that considers generation investments as a response to transmission developments and the Shapley Value from cooperative game theory. Conveniently, this method provides a unique allocation that a) satisfies an axiomatic definition of fairness and b) considers each country's expected marginal contribution to the cooperative agreement. We demonstrate our results for three planned cross-border transmission projects in the North Sea. <!--EndFragment-->

**2 - Graphical Models for Transmission Expansion Planning**

David Pozo, PhD, Skolkovo Institute of Science and Technology, Moscow, Russian Federation, Ivan Zorin

Transmission Expansion Planning (TEP) should account for the possible futures foresight of parameters such as demand's growth, level of renewables' penetration or cost of primary energy resources. Although the TEP solution should accommodate to any possible realization of uncertainties, the decision has to be made beforehand. Therefore, TEP problem should thoughtfully recognize all potential uncertainties, via experts' knowledge and forecasting tools. However, finding distributions for uncertain parameters is a hard problem too. Our proposed approach to addresses the TEP problem as a combination of graphical models and mathematical optimization techniques.

**3 - Environmental Impact on the Development of the Expansion of Power Transmission**

Enzo E. Sauma, Pontificia Universidad Catolica de Chile, Ave. Vicuna Mackenna 4860, Santiago, Chile, Carlos Matamala, Rodrigo Moreno

We develop a model for expanding the capacity of the electrical system that co-optimizes the expansion planning of generation and transmission and considers different levels of coordination among market agents. Using this model, we study the influence of environmental and social externalities in the planning of the expansion of power transmission. We show there may be significant interactions between the environmental and social externalities and the development of the power transmission expansion.

**4 - Economic Externalities in Transmission Network Expansion Planning**

Javier Contreras, Univ de Castilla-La Mancha, E. T. S. de Ingenieros Industriales, Campus Universitario, Ciudad Real, 13071, Spain, Hans Alayo, Marcos J. Rider

Since opportunity costs in transmission and generation capacity are dependent, externalities arise when investment decisions are decentralized. When generation and transmission investment decisions are made separately, generation investment introduces negative externalities to transmission planning. A centralized multistage stochastic model is formulated for finding the Pareto optimal solution of investments in transmission and generation capacity. Using the model, we show some examples of externalities in transmission planning for the IEEE 24-bus test system and the Peruvian system.

## ■ SC46

North Bldg 228B

**Distributed Energy Resources**Sponsored: Energy, Natural Res & the Environment/Energy  
Sponsored Session

Chair: Andrea Staid, Sandia National Labs, Albuquerque, NM, 87108, United States

**1 - Practical Challenges in Real-time Optimization of Distributed Energy Resources**

Cesar A. Silva-Monroy, Senior Scientist, EnerNOC, 24001 East Mission Ave. Suite 102, Liberty Lake, WA, 99019, United States

Distributed Energy Resources (DERs) offer tremendous potential for increasing the flexibility and resilience of the grid. DERs can help utilities and grid operators to cost-effectively manage electricity demand growth, congestion, power quality, and reserve allocation. DERs can also increase reliability while reducing electricity costs for end consumers. In this presentation we will review typical Behind-The-Meter (BTM) value streams found in DER optimization applications from an aggregator or energy manager perspective. We'll then discuss practical challenges that arise when deploying real-time optimization in BTM applications and offer insights on how to address some of them.

**2 - Resources in the MIP Gap of Near-optimal RTO-scale Unit Commitment Solutions**

Brent Eldridge, Johns Hopkins University, 811 Park Ave. #5, Baltimore, MD, 21201, United States

Electricity markets schedule resources by solving a large-scale mixed integer program called the unit commitment (UC) problem. Due to the size of the market, UC is almost never solved to a provably optimal solution. It is instead solved to satisfy an optimality gap that may be larger than small distributed resources which are expected to be more prevalent in the coming decades. This presentation discusses arbitrariness and consistency of resource profitability in near-optimal integer solutions and how these issues are affected by new pricing methods. Preliminary results for a large-scale unit commitment problem are presented.

**3 - Distributed Resources and Complications for System Planning**

Andrea Staid, Sandia National Laboratories, Albuquerque, NM, 87108, United States, Anya Castillo, Jean-Paul Watson

Distributed energy resources, such as rooftop solar, are growing quickly. Utility companies and grid operators often have limited visibility into these resources, and obtaining accurate energy production forecasts for uncertain resources is challenging. Here, we evaluate the impact of the quality of information available to operators in terms of capacity and forecast quality on overall grid operations. We also study the differences in forecast error by resource type to determine the impacts of growing distributed capacities in system planning.

**4 - Stochastic Optimization with Risk Aversion for Virtual Power Plant Operations**

Anya Castillo, Sandia National Laboratories, MS 1027, P.O. Box 5800, Albuquerque, NM, 87185-1027, United States

Sandia National Laboratories undertook a three-year research program to create the components of a real-world secure, virtual power plant (VPP) that could simultaneously participate in multiple markets. We determine optimal offers using a rolling horizon control that solves a two-stage stochastic program (SP) with risk aversion for each day-ahead and real-time problems. Real clear sky and cloudy sky results indicate that the overall risk exposure for each offer strategy can enable the VPP operator to hedge against the volatility introduced by aggregating renewable DERs.

## ■ SC47

North Bldg 229A

**Behavioral Challenges in Policy Analysis with Conflicting Objectives**

Emerging Topic Session

Chair: Margaret M. Wiecek, Clemson University, Mathematical Sciences Dept, Clemson, SC, 29634-1907, United States

**1 - Behavioral Challenges in Policy Analysis with Conflicting Objectives**

Gilberto Montibeller, Loughborough University, School of Business & Economics, Loughborough, LE11 3TU, United Kingdom

Public policy problems are rife with conflicting objectives: efficiency versus fairness, technical criteria versus political goals, costs versus multiple benefits. Multi-Criteria Decision Analysis provides robust methodologies to support policy makers in making tough choices and in designing better policy alternatives when considering these conflicting objectives. However, there are important behavioral challenges in developing these models. Policy analysis works with groups of policy makers, modeling their decision, facilitating their discussions, and representing preferences and priorities. The overarching goal is to improve decision processes and provide support to evidence-based decision making, taking into account public priorities and the inherent uncertainties that long term horizons and complex systems present. Key challenges in those interventions are the use of expert judgments, whenever evidence is not available, the elicitation of preference and priorities from policy makers and communities, and the effective management of group decision processes. Human behavior has a major influence on each of these challenges: experts might be biased in their estimates, individuals may be unable to express clearly their preferences, and groups may present dysfunctional dynamics. Extensive developments in behavioral decision research, social psychology, facilitated decision modeling, and incomplete preference models shed light on how decision analysts should address these issues to provide better decision support and develop high quality decision models. This tutorial discusses the main findings of these extensive, but rather fragmented, literatures. These guidelines are illustrated using policy analysis interventions conducted over the last decade for several organizations, such as the evaluation of capabilities of health systems against rabies for the World Health Organization (WHO), the prioritization of low moisture foods for the Food and Agriculture Organization of the United Nations (FAO), the assessment of bio-security threats for the UK Department of Environment Food and Rural Affairs (DEFRA), the evaluation of malaria treatment kits for the Malaria Consortium/USAID, and the prioritization of value-for-money studies for the UK National Audit Office.

## ■ SC48

North Bldg 229B

**Forest Management and Conservation**

Sponsored: Energy, Natural Res &amp; the Environment Forestry

Sponsored Session

Chair: Jordi Garcia-Gonzalo, Forest Sciences Centre of Catalonia (CTFC), Ctra St Lloren de Morunys km2, Solsona, 25280, Spain

**1 - PRISM - Harvest Scheduling using the 2012 Planning Rule**

David Anderson, USDA Forest Service, Albuquerque, NM, United States, Dung Nguyen, Eric Henderson, Yu Wei

The US Forest Service developed the Spectrum software in the mid 1990's to help determine estimates of sustainable timber harvest volume as required by the 1976 National Forest Management Act. In the ensuing years the computing environment has changed. Additionally the 2012 Planning Rule updated the US Forest Service's interpretation of the Act. The Northern Region in collaboration with Colorado State University developed a new linear programming model generator called PRISM to address these changes. PRISM uses a hybrid Model I and Model II formulation with a goal programming objective. The software uses an open source philosophy. Interface design and results from two Forest Plans are shown.

**2 - Prioritizing Restoration of Fragmented Landscapes for Wildlife Protection: A Graph-theoretic Approach**

Denys Yemshanov, Natural Resources Canada, 1219 Queen Street East, Sault Ste. Marie, ON, P6A2E5, Canada, Robert G. Haight, Frank Koch, Mark-Andre Parisien, Tom Swystun, Barber Quinn, Cole Burton, Ning Liu, Salimur Choudhury

Restoring habitat connectivity is critical for wildlife conservation in fragmented landscapes. We propose a network-based habitat restoration model with connected area requirements and a budget constraint. The MIP formulation shares some similarities with a budget-constrained Generalized Steiner Network problem. The objective is to determine restoration strategies that maximize the connected habitat capacity accessible to a wildlife species in a fragmented landscape. We apply the model to habitat restoration for woodland caribou in boreal forest in Cold Lake area, Alberta, Canada.

**3 - Acceptance Sampling for Surveillance of Forest Pests**

Robert G. Haight, US Forest Service, 1992 Folwell Ave, Saint Paul, MN, 55108, United States, Denys Yemshanov, Robert Venette, Cuicui Chen, Ning Liu, Frank H. Koch, Christian MacQuarrie, Krista Ryall

Surveillance of forest pests helps foresters plan for pest control. We use acceptance sampling to delimit the extent of an infestation. The forester identifies potential survey sites and chooses the number of trees to inspect in each site given its tree density, infestation rate, and detection rate. If one or more trees in the sample is infested, the site is subject to pest control. The objective is to allocate a fixed survey capacity to sites to maximize the number of detected infested sites subject to an upper bound on the expected number of undetected infested trees. We formulate this objective as a MIP problem and apply it to surveillance of emerald ash borer, a destructive forest pest in Winnipeg, Canada.

**4 - Modelling and Solving Biodiversity Conservation Plans under Uncertainty**

Jordi Garcia-Gonzalo, Forest Sciences Centre of Catalonia (CTFC), Solsona, 25280, Spain, Eduardo Ivarez-Miranda, Andres P. Weintraub, Virgilio Hermoso, Jose Salgado-Rojas

Limited conservation budgets require prioritizing which management actions to implement and where to maximize the long-term persistence of biodiversity. Modelling this problem considering multiple species and actions is not an easy task. In addition, there is uncertainty in the data use for modelling and solving this problem (e.g. presence of the species, response to the action...). We propose a MIP-based framework for modeling and solving this problem. We seek for plans that maximize expected ecological benefit while minimizing spatial fragmentation and considering budget restrictions.

## ■ SC49

North Bldg 230

**Supply Chain Planning in the Petrochemicals Sector**

Sponsored: Energy, Natural Res &amp; the Environment/Natural Resources Petrochemicals

Sponsored Session

Chair: Ethan Malinowski, SUNY-Buffalo, Buffalo, NY, 14216, United States

**1 - Dynamic Programming Approach for Maintenance Operations Budgeting**

Alcides Santander-Mercado, Associate Professor, Universidad del Norte, km 5 v a Puerto Colombia, Barraquilla, Colombia, Catalina Torres-Diaz

Budgeting in industrial maintenance operations has been approached using forecasting methods and machine live cycle techniques. However, it is commonly ignored how the cost change overtime due technology upgrades, labor or availability of replacement parts. The comprehensive analysis of the maintenance cost and the new technology offered by their suppliers will help managers to decide whether continue with the original maintenance plan, draw by the manufacturer, or replace the machine. This research presents a Dynamic Programming approach to address the budgeting of maintenance operations, including a case study related to an application of this approach in a chemical company.

**2 - Supply Chain Planning for Production Networks with Highly Flexible Modular Plants**

Tristan Becker, Ruhr University Bochum, Bochum, Germany, Stefan Lier, Brigitte Werners

Modular production concepts are investigated to meet increased variability of product demands in process industries. Modular plants consist of standardized process modules, installed in containers, which allow for quick assembly, disassembly and relocation of production plants. Depending on the combination of process modules, different production capabilities are associated with a production plant. We apply new mixed integer programming formulations for production network planning under consideration of the new flexibility options to a real-world case study from the chemical industry.

**3 - A Practical Approach to the Vehicle Routing Problem in Cylinder Gas Distribution**

Soma Toki, Tokyo Gas Co., Ltd., 1-5-20 Kaigan, Minato-ku, Tokyo, 105-8527, Japan, Naoshi Shiono, Eiji Murakami

Recently, companies can remotely monitor the quantity of daily propane usage and plan their daily distribution operations with communication devices. In the liquefied petroleum gas (LPG) logistics industry, it is desirable that delivery plans for a week or more are always prepared. Companies can prospect a quantity of the jobs in the future with this plan. But when a LPG company has much of the distribute destinations, it is unrealistic to calculate the plan in one time. The company is required to disperse or reduce the calculation load for making the plans. In this work, we introduce some approaches to install the software for one LPG distributor.

#### 4 - Packaged Gas Supply Chain Planning with SKU Rationalization: Customer-selection and Incentivization-based Methodologies

Ethan Malinowski, University at Buffalo (SUNY) Buffalo, NY, 14216, United States, Mark Henry Karwan, Lei Sun

We present a multi-component project, applying SKU rationalization (in the form of a variant of product substitution) towards a traditional supply chain planning problem including production, allocation, and distribution decisions. A customer-selection heuristic is developed and shown to perform very well compared to a full MILP formulation, which includes customer selection for substitution as an explicit decision. Lastly, incentivization strategies are studied in an effort to reduce lost demand via product substitution, while simultaneously ensuring adequate business profit.

## ■ SC50

North Bldg 231A

### Joint Session Practice/Practice Curated: Edelman Reprise I

Sponsored: INFORMS Section on Practice (formerly CPMS)  
Sponsored Session

Chair: Anne G. Robinson, Verizon Wireless, Basking Ridge, NJ, 07920, United States

Co-Chair: Carrie Beam, University of Arkansas, Walnut Creek, CA, 94596, United States

#### 1 - China National Petroleum

Zuo-Jun Max Shen, University of California Berkeley, 4141 Etcheverry Hall, Mail code 1777, Berkeley, CA, 94720-1777, United States

Abstract not available.

#### 2 - Turner Blazes a Trail for Audience Targeting on Television with Operations Research and Advanced Analytics

J. Antonio Carbajal, Turner Broadcasting System, Inc., Atlanta, GA, USA

Turner has designed and implemented innovative and integrated forecasting and optimization models that power audience targeting solutions disrupting decades-old paradigms and business processes in the media industry, and producing significant sales and advertisement efficiencies for Turner and its clients. Turner is on track to sell 50 percent of its inventory through audience targeting by 2020, representing billions in ad revenue.

#### 3 - Europcar Integrates Forecast, Simulation and Optimization Techniques in a Capacity and Revenue Management System

Europcar, Y, Aruba.

Europcar, the leading European car rental company, partnered with ACT Operations Research to create Opticar, a complex decision support system. Opticar features forecasts, discrete event simulations and optimization techniques providing an integrated approach to revenue and capacity management. Opticar anticipates future demand for Europcar's vehicles fleet, up to six months in advance, improving capacity management. In addition, Opticar enables Europcar to optimize its approach to revenue management and rental pricing, taking into account competitors information, the currently available fleet and expected demand for vehicles. Opticar provides a shared mathematical approach used as a starting point for all daily operations to nine Europcar's corporate countries.

## ■ SC51

North Bldg 231B

### Joint Session OMS/Practice Curated: Applications in Scheduling

Emerging Topic: Project Management and Scheduling,  
in Memory of Joe Leung,  
Emerging Topic Session

Chair: Rodrigo A. Carrasco, Ph.D., Universidad Adolfo Ibáñez, Santiago, Chile

#### 1 - A Scheduling Problem Motivated by Cybersecurity and Adaptive Machine Learning

Nourhan Sakr, Columbia University, New York, NY, 10027, United States, Clifford Stein, Ojas Parekh, Cynthia Phillips, Vladlena Powers

We consider a multiple-machine problem where each machine is associated with its predetermined sequence of jobs. A machine may start a new job if it is given a signal (a "take") to do so. A take is global across all machines. Given a fixed budget of takes, we schedule takes to minimize total idle time. This problem comes from a stochastic-programming exploration of a cybersecurity game. We

also find another interpretation that applies this problem to adaptive machine learning. We motivate and define the problem, give some preliminary complexity results, and discuss practical (in)tractability.

#### 2 - The Value of Flexibility in Bottling Operations in the Wine Industry under Sequence Dependent Setup Times

Alejandro Francisco Mac Cawley, Pontificia Universidad Católica de Chile, Vicuna Mackenna 4860, Santiago, 7820436, Chile, Sergio Maturana, Mauricio Varas

Wineries must optimize their bottling process and deal with many products to be processed, high-demand variability and sequence dependent setup times. Under these conditions, managers must generate scheduling plans. We look at flexible strategies such as the postponement of the labeling of bottled wines; to gain productivity in the process. We study the performance impact of implementing flexible strategies by developing a multi-stage mixed-integer stochastic programming model with full recourse for demand scenarios. Results show benefits of implementing flexible strategies under given capacity of the system, demand variability and setup times.

#### 3 - Scheduling Surgeries with Variable Times: The Value of More Data

Rodrigo A. Carrasco, Diagonal Las Torres 2640, Of. 532, Edificio C, Santiago, 7941169, Chile

Although operating room scheduling has been studied since the early 60's, dealing with surgery variability has been one of the main difficulties when implementing scheduling tools. In this work we present a way of incorporating such variability by using chance constraints to improve schedule performance. We develop specific constraints, through data analysis of real instances, which improve the schedule, reducing the need for overtime but without affecting the utilization significantly..

#### 4 - Bicriteria Job Scheduling with Split Lots

Rasaratnam Logendran, Professor, Oregon State University, School of Mech Industrial & Mfg Engr, Rogers Hall Rm 204, Corvallis, OR, 97331-6001, United States, Ayush R. Aryal

An algorithm, which incorporates tabu search into the framework of path relinking, is presented to solve a job shop scheduling problem, consisting of  $M = \{1, 2, \dots, m\}$  machines. Each job  $j \in J = \{1, 2, \dots, n\}$  consists of  $i(j)$  ordered operations. During an operation, a job is split or merged into  $k_i(j)$  split-lots. Each split-lot operation can be performed by a subset of machines in  $M$ . The production is discontinuous within a two-week planning horizon. The objective function focuses on minimizing a linear combination of weighted flowtime and weighted tardiness. Three initial solution finding mechanisms are used and their comparative performance in the algorithm is evaluated using various problem instances.

## ■ SC52

North Bldg 231C

### Section Leaders & Research on Opinions and Facts

Emerging Topic: Social Media Analytics

Emerging Topic Session

Chair: Theodore T. Allen, Ohio State University, Columbus, OH, 43210-1271, United States

#### 1 - Determining Twitter Users Opinions using Research

Evan Munson, Air Force Institute of Technology, Wright Patterson AFB, OH, 45385, United States, Christopher M. Smith

The rise in popularity of social media has changed the World Wide Web from a static repository to a dynamic forum for anyone to voice their opinion across the globe. People have become increasingly used to sharing their opinions on social media platforms. Harvested data, analyzed for opinions and sentiment can provide insight into a population. This research utilizes Twitter data to examine the sentiment associated with tweets. An approach utilizing Latent Dirichlet Allocation topic modeling was utilized to differentiate between tweet topics. A lexicographical dictionary was then utilized to classify sentiment. This method provides insight into the sentiment contained within the Twitter data.

#### 2 - Comparative Analysis of Information Flow and Rumor Debunking and Spreading through Twitter During Hurricanes Harvey and Irma

Kyle Hunt, University at Buffalo, SUNY, 317 Bell Hall, Buffalo, NY, 14260, United States, Jun Zhuang

The topic of the comparative analysis of information flow and rumor debunking is studied both empirically and theoretically.



### 3 - Impact of Fake News and Ambiguity on the Equity Value of Social Media Platforms - Evidence from Twitter

Srikar Velichety, University of Memphis, Memphis, TN, 38111, United States, Utkarsh Shrivastava

We investigate the impact of Fake News and the ambiguity in its detection on the equity value of Social Media platforms. Using prior research, we develop hypotheses about the negative impact of fake news and ambiguity on the medium where it is incubated and propagated. We test these hypotheses using a large scale annotated dataset of real-world events posted to Twitter over a 140-day period. Using extended vector auto-regression, we estimate the impact of the presence of fake news and the ambiguity it causes on the short and long-term equity value of social media. Our results show that the presence of tweets about a single fake event is linked to a decrease in market return of the social media platform by 0.035% and increase the risk by 0.005%.

### 4 - Using DOE and Social Media to Spread Policy Information

Theodore T. Allen, Ohio State University, 210 Baker Systems, 1971 Neil Ave, Columbus, OH, 43210-1271, United States

We illustrate how experimental design can aid in directing social media campaigns to target voter types most receptive to policy information attitudinally and informationally. Both voter survey and google analytics experiments are studied together with resolution V designs and optimal alternatives. Issues relate to the environment, taxes, marijuana, and guns.

## ■ SC53

North Bldg 232A

### Pricing and Equilibrium Finding in Combinatorial Markets

Sponsored: Auction and Marketing Design

Sponsored Session

Chair: Benjamin Lubin, Boston University, Boston, MA, 02215, United States

Co-Chair: Sven Seuken, University of Zurich, Zurich, 8050, Switzerland

#### 1 - Revealed Preference and Activity Rules in Dynamic Auctions

Oleg V. Baranov, University of Colorado-Boulder, 256 UCB, Boulder, CO, 80309, United States, Lawrence M. Ausubel

We provide a general treatment of activity rules in auctions: constraints that limit bidding in future rounds based on past bids. Traditional point-based activity rules are effective for homogeneous goods, but are simultaneously too strong and too weak for general environments. Rules operationalizing the generalized axiom of revealed preference (GARP) enable straightforward bidding. We prove they are the weakest rules that prevent weak axiom (WARP) violations while never producing “dead ends”. In addition, GARP rules are robust to limited amounts of learning. We also provide empirical examples where bidders generally comply with GARP and violations suggest strategic manipulation.

#### 2 - Adaptive Price Combinatorial Auctions

Benjamin Lubin, Boston University, School of Management, 595 Commonwealth Avenue, Boston, MA, 02215, United States, Sebastien Lahaie

We introduce a novel iterative combinatorial auction based on adaptive polynomial pricing. The mechanism starts with linear prices; then upon provably detecting that the current price structure cannot clear the market, expands the structure to guarantee progress. We provide theoretical and experimental evidence for the effectiveness of the design.

#### 3 - Spectrum Repacking in the Incentive Auction

Neil Newman, University of British Columbia, 1590 West 15th Avenue, Unit 5, Vancouver, BC, V6J 2K6, Canada, Kevin Leyton-Brown, Paul Milgrom, Ilya Segal

In 2016-17 the FCC conducted an “incentive auction” to repurpose radio spectrum from broadcast television to wireless internet. The auction yielded \$19.8 billion, \$10 billion of which was paid to broadcasters for voluntarily relinquishing their licenses. A crucial element of the auction design was the construction of a solver, dubbed SATFC, that determined whether sets of stations could be “repacked” in this way; it needed to run every time a station was given a price quote. To evaluate the impact of our solver, we built an open-source reverse auction simulator. We found that SATFC substantially outperformed other alternatives at national scale.

### 4 - Computing Bayes Nash Equilibria in Combinatorial Auctions

Sven Seuken, University of Zurich, Binzmuhlestrasse 14, Zurich, 8050, Switzerland, Vitor Bosshard, Benedikt Buenz, Benjamin Lubin

We present two new algorithms for computing symmetric pure epsilon-BNEs in CAs with continuous values and actions. We evaluate our algorithms in the well-studied LLG domain, against a benchmark of 16 CAs for which analytical BNEs are known. Furthermore, for CAs with quasi-linear utility functions and independently distributed valuations, we derive a theoretical bound on epsilon. Finally, we introduce the new Multi-Minded LLLGG domain with eight goods and six bidders and apply our algorithms to finding an equilibrium in this domain. Our algorithms are the first to find an accurate BNE in a CA of this size.

## ■ SC54

North Bldg 232B

### BOM Best Working Paper Competition

Sponsored: Behavioral Operations Management

Sponsored Session

Chair: Julie Niederhoff, Syracuse University, Syracuse University, Syracuse, NY, 13244, United States

#### 1 - Increased Transparency in Procurement: The Role of Peer-Effects

Ruth Beer, Indiana University, Bloomington, IN, USA, Ignacio Rios, Ruth Beer.

We study the effects of increased transparency in a setting where purchasing decisions are delegated to individual employees as opposed to being centrally managed by an organization. We develop a theoretical model which incorporates peer effects resulting from transparency and we show that there exists a spillover region where an employee is more likely to choose the expensive supplier when he observes that his peer did so. We confirm this finding with a laboratory experiment. We also find that employees whose decisions are observed are less likely to choose the expensive supplier, in line with what the social norm of appropriate behavior prescribes.

#### 2 - Private Information and Endogenous Matching in Supply Chains

Kyle Hyndman, University Texas-Dallas, Richardson, TX, USA, Andrew M. Davis

We investigate a supply chain setting where a supplier's cost may be private information (but they may disclose it) and buyers and suppliers may endogenously match into pairs. After forming pairs, the two parties engage in a dynamic bargaining setting. Suppliers always make less than theory predicts, whether their cost is known or private information. This effect is especially pronounced under private information for high cost suppliers, because buyers make more aggressive bargaining offers in such a setting. Thus, contrary to theory, a second result is that higher cost suppliers actually benefit from disclosing their private costs, in an effort to achieve a more favorable outcome while bargaining.

#### 3 - From Noise to Bias in Linked Supply Chain Decisions

Daniel Feller, Dartmouth College, Hanover, NH, USA, Jordan D. Tong

Researchers in Behavioral Operations Management have made considerable progress on documenting the random error inherent to human decision behavior and incorporating it into Operations Management models. However, the field is also fundamentally interested in managing processes, and comparably little work has studied how noisy behavior plays out in sequences of unique linked decisions. In this paper, we study the fundamental choose-forecast-invest task combination: a decision maker must (a) choose which product to sell, (b) make a demand forecast for the chosen product, and (c) make an investment decision for the chosen product. Through behavioral models and laboratory experiments, we show how adding unbiased random noise to the process leads to a downstream systematic bias of overinvestment. This bias arises due to the way that random noise is filtered through the sequence of linked decisions and statistical naivety on the part of the decision-maker. Random noise in the demand forecast increases the overinvestment bias, but random noise in the product choice actually decreases the bias. Consequently, under certain parameters, being less rational (i.e., more random) in product choice can actually yield higher profits. Tasks in which information requires greater human interpretation are shown to increase the bias. Finally, employing a task-decomposition approach, we examine when separating product choice and investment decision-making across different people can reduce the bias and improve performance.

## ■ SC55

North Bldg 232C

### Joint Session Practice Curated/Practice Sports Analytics II

Sponsored: SpORts

Sponsored Session

Chair: Stephen Hill, UNC Wilmington, United States

#### 1 - NFL versus NCAA Football Decision Making Analysis

Stephen Hill, UNC Wilmington, United States

In this work in game win probability models are developed for NFL and NCAA football. These models are compared and then used to evaluate decision making approaches. Additionally, consideration is given to measuring in game win probability volatility.

#### 2 - Real-Time NBA Playoff Elimination

Mark Husted, Colorado School of Mines, 816 20th Street, Golden, CO, 80401, United States, Alexandra M. Newman, Eli Olinick

The NBA is divided into two conferences, each of which is comprised of fifteen teams, and the top eight teams from each conference compete in the playoffs. An integer-programming model determines when a team has been eliminated from the playoffs before the completion of the regular season. There are instances in which teams' winning percentages are tied. Ties are broken using seven independent criteria based on the number of teams tied. The results are published on the RIOT website so fans can follow their favorite teams' playoff standings. We compare the time at which (and day on which) these results are published to the NBA official standings; in many cases, RIOT notifies the public prior to the NBA.

#### 3 - Learning from Success and Failure at the Speed of Formula One

Michael A. Lapré, Vanderbilt University, 401 21st Avenue South, Nashville, TN, 37203, United States, Candace Cravey

KC, Staats and Gino (2013) found that surgeons learn from their own success and from others' failure. Unlike surgery, in Formula One racing, success is rare and competitive. Using data since Formula One started in 1950, we investigate driver learning from own experience and teammates' experience with both success and failure. We find that drivers learn from own success, teammates' success, as well as own car failures. We use characteristics of success to explain observed learning effects.

#### 4 - Maximizing National Hockey League Goal Differential through the Examination of Line Orders and Lengths

William Davis, Student, Slippery Rock University, Slippery Rock, PA, 16057, United States, Jacob Lindey

While graph theory and mathematical predictive measures rarely enter into dialogue with hockey, these are the very concepts that would provide National Hockey League managers with better chances of winning through more efficient ice time. We examine and implement these concepts to manipulate line orders and lengths to maximize goal differential for any given team. In addition, we break down our easy-to-use interface designed for managers.

#### 5 - A Classification and XML Framework for Round Robin Sports Timetabling Problems

Dries Goossens, Ghent University, Tweekerkenstraat 2, Gent, 9000, Belgium, David Van Bulck, Jorn Schonberger, Mario Guajardo

In the sports timetabling literature, most problems assume different constraints and objectives. Often, one specific case study is discussed, with an accompanying solution method. This lack of structure makes it hard to compare problem instances and to assess algorithmic performance. We present a 3-field classification scheme for round-robin sports timetabling problems. For the instance definition and its solution(s), we propose two XML-file-based templates and a C++-library (RobinX) to evaluate both files. We present a web application that should encourage exchanging instances and solutions, and eventually lead to more general insights.

## ■ SC56

West Bldg 101A

### HAS Distinguished Scholar Lecture Diwakar Gupta

Sponsored: Health Applications

Sponsored Session

Chair: Ebru Korular Bish, Virginia Tech, Blacksburg, VA, 24060, United States

Co-Chair: Tinglong Dai, Johns Hopkins University, Baltimore, MD, 21202, United States

#### 1 - The US Deceased-donor Organ Procurement and Utilization System

Diwakar Gupta, Professor, University of Texas, 2110 Speedway

Stop B6000, Austin, TX, 78712, United States

The annual supply of human organs in the US has been more or less stable in recent years. The demand has outstripped supply and the national waitlist continues to increase every year. This supply-demand imbalance leads to human suffering, failure to access transplantation, and waitlist deaths. Many Operations Researchers have focused attention on the national system of matching and prioritizing potential transplant recipients, which affects organ utilization. Some other works have focused on geographic disparities between supply and demand and suggested improvements via redesign. These efforts focus only on a subset of practices at both procurement and utilization ends of organ supply that result in reduced supply. This talk will describe current practices across the organ procurement and transplantation system that may benefit from OR models, present preliminary models, and suggest research opportunities.

## ■ SC57

West Bldg 101B

### HAS Session

Sponsored: Health Applications

Sponsored Session

Chair: Jayashankar M. Swaminathan, University of North Carolina Chapel Hill, Chapel Hill, NC, 27599-3490, United States

Co-Chair: Sandeep Rath

#### 1 - Financial Incentives Under CPC+

Elodie Adida, University of California at Riverside, CA, United States, Fernanda Bravo

The Centers for Medicare and Medicaid Services have recently launched the Comprehensive Primary Care Plus (CPC+) initiative, aiming at improving primary care delivery by changing the way providers are paid for their services. CPC+ includes a capitation payment, a reduced fee per visit, as well as a performance-based payment incentive. Under this program, physicians are encouraged to use alternative care delivery methods (phone calls, e-visit, in-home nurse visits, etc.). We study how this payment system impacts providers' care delivery decisions, patient welfare and payer cost.

#### 2 - Sustainability Planning for Healthcare Information Exchanges

Tharanga Rajapakshe, Chelliah Sriskandarajah, Subodha Kumar, Arun Sen

We investigate a multi-period two-service model where a HIE offers (i) the healthcare information sharing service, and (ii) the supplier rebate program. Our proposed model is primarily based on our interactions with a number of HIE providers in Texas. First, we present structural properties and equilibrium solution for our model. Then, based on extensive computational experiments, we present several useful managerial insights for the HIE provider as well as the policy-makers.

#### 3 - Coordinated Care for Mental and Physical Health

Sandeep Rath, University of North Carolina at Chapel Hill - Kenan Flagler, CB #3490, McColl Building, McColl 4705, Chapel Hill, NC, 27599, United State, Jayashankar M. Swaminathan

Multiple clinical trials have demonstrated the benefits of coordinating treatment of mental health conditions like depression and chronic physical conditions like diabetes. However, sustainability of coordinated care outside trial settings has not been fully demonstrated. A sustainable coordinated care will be revenue neutral for the providers and improve patient outcomes. Towards this, we propose a mathematical optimization model which would optimize care management plans to improve patient outcome while balancing revenue and resource usage costs.

#### 4 - Estimating Patient Flow Models via Robust Queueing Theory

Chaithanya Bandi, Kellogg School of Management, Northwestern University, 2211 Campus Dr, room 4169, Evanston, IL, 60208, United States

In this paper, we consider the statistical study of partially observed queueing systems arising in application areas such as Hospital networks, data centers, and cloud computing systems. Because these services operate under strict performance requirements, a statistical understanding of their performance is of great practical interest. A key challenge in these settings is that the data are incomplete, because recording detailed information about every request to a heavily used system can require unacceptable overhead. We propose an analytically tractable approach for studying inference problems in these queueing systems. Our approach is based on the Robust Queueing framework.

## ■ SC58

West Bldg 101C

**Healthcare Operations: Improving Access to Care and Patient-Welfare**

Sponsored: Health Applications

Sponsored Session

Chair: Sila Cetinkaya, Southern Methodist University, Dallas, TX, 75205, United States

Co-Chair: Olga Bountali, Southern Methodist University, Dallas, TX, 75219, United States

**1 - Analysis of Primary Care Delivery with E-Visits: Improving Access to Care and Profitability**

Xiang Zhong, University of Florida, Aditya Mahadev Prakash

We consider a medical institution who offers both office and e-visit to their panel patients. A key planning problem is to determine the medical resource capacity that improves access to care for patients and ensures profitability of the medical institution. A novel analytical framework for modeling a care delivery system with two horizontally substitutable channels and a heterogeneous patient population is proposed. We identify that when the service system is of high traffic intensity, based on patient segmentation, medical institutions can equip their e-visit services with an optimal amount of resources to ensure an economical outcome while providing care to more patients.

**2 - Modelling Enrollment in Clinical Trials**

Erinc Albey, Ozyegin University, Istanbul, 34794, Turkey

Clinical trial planning and execution depends on enrollment, yet few tools exist that allow prediction of subject accrual to inform study design and conduct. We sought to develop a model to estimate the probability that a site will enroll a specified number of subjects in a trial within a given time interval, allowing for better clinical trial planning and execution. We hypothesized that the enrollment process is a finite, first-order, discrete time, homogeneous Markov chain. We based our analyses on data from two large multicenter, completed clinical trials. We modeled the enrollment performance of sites as a discrete set of states (zero/low/medium/high enrollments) over a given time interval and assessed whether the model accurately reflected trial enrollment. We also performed a set of Monte-Carlo simulations based on this Markov model to estimate the time required for the trial to enroll a predetermined number of patients. The enrollment prediction performance of the proposed Markov model is superior to linear and polynomial regression models, especially in the early phases of the trial. These estimates may be used in predicting the overall duration and in managing future similar trials in real-time.

**3 - The Impact of Information Sharing on Organ Transplantation: A Simulation Model**

Michael Hahsler, Southern Methodist University, Bobby B. Lyle School of Engineering, P.O. Box 750123, Dallas, TX, 75275, United States, Zahra Gharibi

Recently, several changes to the kidney allocation rules were approved, and modern IT solutions are developed to improve kidney assignment. We present a flexible simulation framework that considers the effect of several important factors for organ transplantation. We use the model to investigate how the optimal individual-level center listing and kidney acceptance decisions are affected by differences in supply due to different allocation rules. At the macro-level, we evaluate the potential effect of information sharing on the social welfare and organ discard rates.

**4 - Improving the Uninsured Patients' Experience: Practice vs. Theory**

Olga Bountali, Southern Methodist University, 4210 Fairmount Street, Apartment 3063, Dallas, TX, 75219, United States, Sila Cetinkaya, Farnaz Nourbakhsh

Under EMTALA, the current practice of care delivery for the uninsured prescribes that patients receive treatment only after being evaluated as in 'emergent, life-threatening condition'. This practice often leads to excessive overhead cost, severe treatment delays, and congestion at publicly funded hospitals with a hefty impact on the cost and quality of healthcare for the uninsured. Existing literature in service operations offers abundant ideas for improving both cost and quality of care including but not limited to congestion mitigation strategies via alternative service protocols. We explore and compare the value of patient-centric service protocols relative to the current practice.

## ■ SC59

West Bldg 102A

**Joint Session HAS/Practice Curated: Stochastic models of Hospital Admission and Discharge Services**

Sponsored: Health Applications

Sponsored Session

Chair: Nan Kong, Purdue University, West Lafayette, IN, 47906-2032, United States

Co-Chair: Michelle M. Alvarado, University of Florida, Gainesville, FL, 32611-6595, United States

**1 - Stochastic Models for Inpatient Discharge Planning**

Maryam Khatami, Texas A&amp;M University, College Station, TX, USA; Michelle M. Alvarado, Nan Kong, Pratik J. Parikh, Mark Lawley.

The inpatient discharge planning problem requires the efficient assignment and sequencing of ready-for-discharge patients to resources. Delay in discharge processes deteriorates patient satisfaction and increases hospital costs. We model and solve the inpatient discharge planning problem as a two-stage stochastic program with uncertain inpatient discharge processing time and bed request times. The objective is to minimize patient dissatisfaction, discharge lateness, and patient boarding. We derive managerial insights by comparing the results of a two-stage stochastic program, the mean value problem, and two heuristics from current practice using simulation modeling.

**2 - Missed Opportunities in Preventing Hospital Readmissions: Redesigning Post-discharge Checkup Policies**

Xiang Liu, University of Michigan, Ann Arbor, MI, United States, Mariel Lavieri, Jonathan Helm, Ted Skolarus

Hospital readmissions affect hundreds of thousands of patients, placing a tremendous burden on the healthcare system. Post-discharge checkup can reduce readmissions through early detection of conditions. Our work develops optimal checkup plans to monitor patients following hospital discharge using methods including phone calls and office visits. By analyzing the structure of optimal policies, we develop checkup schedules that mitigate 32% more readmissions.

**3 - Improving Discharge Process at a University Hospital: A System-theoretic Method**

Xiaolei Xie, Tsinghua University, 614 Shunde Building, Beijing, 100084, China, Nan Chen, Zexian Zeng, Xiang Zhong, Maria Brenny-Fitzpatrick, Barbara A. Liegel, Li Zheng, Jingshan Li

This paper introduces a system-theoretic approach to improve inpatient discharge process at a university hospital. The complex hospital discharge process is modeled by a stochastic process with parallel sub-processes, splits, and merges. A system analysis method is introduced to approximate the discharge time and evaluate the mean, variability, and discharge-time performance. It is shown such a method results in a high accuracy in performance evaluation. To improve the discharge process at the university hospital, bottleneck and what-if analyses are carried out and improvement recommendations are discussed.

**4 - Admission Planning Problem with Stochastic Length of Stay**

Jorge Vera, Universidad Catolica de Chile, Dept. Industrial and System Engineering, Santiago, 7820436, Chile, Ana Celeste Batista, David Pozo

Effective admission planning process can improve inpatient throughput and waiting times. The uncertain in the patient's length of stay complex the admission and may cause bottlenecks and long waiting times in the patient's flow. We study the admission planning problem considering uncertain in the length of stay. Classically length-of-stay is modeled as a sum over a time windows constraint. This makes it very complex to consider uncertainty on this variable. In this work, we developed a new formulation in which the length of stay is on the right hand of the constraint by employing a single binary variable.



## ■ SC60

West Bldg 102B

### Joint Session HAS/Practice Curated: Applications of Operations Research to Organ Transplantation

Sponsored: Health Applications

Sponsored Session

Chair: Mariel Sofia Lavieri, University of Michigan, Ann Arbor, MI, 48109-2117, United States

Co-Chair: Wesley Marrero, University of Michigan, 1205 Beal Ave, Ann Arbor, MI, 48109, United States

#### 1 - Optimizing Kidney Sharing to Reduce Geographic Disparity

Sommer Gentry, US Naval Academy, Mathematics Department, 572-C Holloway Road, Annapolis, MD, 21402, United States, Jack Robinson

We use parametric linear programming to investigate tradeoffs in decreasing geographic disparity in kidney transplants. We optimize the sharing of kidney supply between neighboring Donation Service Areas (DSAs) to make the number of kidneys transplanted per incident waitlist candidate similar among DSAs. We adjust the percentage of kidneys recovered in a particular DSA that must be transplanted in that same DSA, to reduce geographic disparity while limiting disruption to existing transplant programs which might otherwise oppose the plan. Surprisingly, even if DSAs retain 90% of their original supply, we can significantly improve the kidney transplant rates in the most underserved areas.

#### 2 - Achieving Fairness in Allocating Uncertain Resources with Applications to Kidney Transplantation

Sanjay Mehrotra, Northwestern University, Chaithanya Bandi

A novel model for fair allocation of uncertain resources becoming available over time is presented. Demand exceeds supply. Supply distribution is constrained by certain logistical requirements. Our goal is to achieve a fair distribution of supply. Fairness objective is stochastic and fractional. We show that a parametric convex optimization problem can be used to identify an optimal solution. We give parametric tractable re-formulations of our model using polyhedral and conic ambiguity sets, motivated from the concepts of robust queues. Numerical results on the performance of the model using data from the US kidney allocation system, which motivated the problem, will be presented.

#### 3 - Cherry-picking Kidneys and Patients: Incentives in Transplant Centers

Mazhar Arikian, Associate Professor, University of Kansas, Lawrence, KS, United States, Baris Ata, Rodney P. Parker

In 2007 the Centers for Medicare and Medicaid Services implemented a set of regulations for transplant centers called conditions of participation (COP). These rules evaluate transplant centers based on one-year patient and organ survival rates post transplantation. According to the COP, centers performing worse than the COP expectation face losing their certification to transplant. Using actual offer and transplant data, we empirically analyze some potential unintended consequences of these regulations such that more risk averse centers choose healthier patients and higher quality organs to transplant. We also discuss some recommendations to policymakers for improving the COP.

#### 4 - The Health and Economic Impact of Presumed Consent Organ Donation on Patients with End-stage Renal Disease

David W. Hutton, University of Michigan, 1015 Fairmount Drive, Ann Arbor, MI, 48105, United States, Huey-Fen Chen, Hayatt Ali, Wesley Javier Marrero Colon, Neehar Parikh, Mariel Sofia Lavieri

We evaluated the impact of opt-out organ donation policies using a Markov model of end-stage renal disease patients in the US. We evaluated policy increasing donation rates by 5%, 25%, or 50% versus the status quo. An opt-out, presumed consent policy would save \$18.3 billion, and gain 137,029 Quality-Adjusted Life-Years over the lifetime of an open cohort of patients on dialysis and on the waitlist for kidney transplantation. When the presumed consent policy only increased donation by 5%, the cost saved was \$4.0 billion, and 29,478 Quality-Adjusted Life-Years were gained. The cost savings were \$32.8 billion and 254,515 Quality-Adjusted Life-Years were saved if the policy increased rates by 50%.

## ■ SC61

West Bldg 102C

### Recent Advancement on Computational Methods in Energy

Emerging Topic: Energy and Climate

Emerging Topic Session

Chair: Feng Qiu, Argonne National Laboratory, Lemont, IL, 60439, United States

#### 1 - Node-based Valid Inequalities for Optimal Transmission

#### Switching Problems

Burak Kocuk, Sabanci University, Istanbul, Turkey, Santanu Subhas Dey, Andy Sun

Although the benefits of line switching are evident in terms of reducing operational cost and improving system reliability, finding the optimal power network configuration is a challenging task due to the combinatorial nature of the underlying optimization problem. In this work, we carry out a polyhedral study related to a certain "node-based relaxation of the Optimal Transmission Switching Problem. We construct an integral extended formulation of this substructure and propose a practical approach to obtain valid inequalities. Finally, we present the results of our computational experiments on difficult test cases from the literature.

#### 2 - Alternative Formulation of Transmission Constraints for Unit Commitment Problems

Alinson S. Xavier, Argonne National Laboratory, Lemont, IL, United States, Feng Qiu, Santanu Subhas Dey

When solving the Security-Constrained Unit Commitment Problem on large-scale transmission networks, one of the most complicating factors is handling transmission and security constraints. The most common formulation used in the industry, based on Injection Shift Factors (ISF), yields very dense constraints, which can cause significant performance issues. In this work, we propose an alternative formulation for transmission constraints, based on network decomposition. Experiments on realistic instances show that this formulation is considerably sparser and can lead to improved running times.

#### 3 - Enumerating Multiple Local Optima for the Optimal Power Flow Problem

Bernard Lesieutre, University of Wisconsin Madison, WI, United States, Daniel K. Molzahn, Dan Wu

The non-convex AC optimal power flow problem generally admits multiple local minima and it can be beneficial to examine the differences between these solutions. We present a deterministic method to trace between optimal solutions. The method relies on recasting the original equations in quadratic form to a more specific geometrically elliptical form, and then applying the Fritz John conditions for optimality. A path tracing algorithm is recursively applied to locate new critical points from previously known solutions. We present results for several challenging test systems.

#### 4 - Machine Learning for Expediting Security Constraint Unit Commitment Solution

Feng Qiu, Argonne National Laboratory, 9700 S. Cass Ave, Building 202, Room C205B, Lemont, IL, 60439, United States, Alinson Xavier, Shabbir Ahmed

Security constrained unit commitment (SCUC) is one of the fundamental optimization problems in power system operations and market clearing. The computational performance of SCUC is crucial for system reliability and market efficiency. We propose to use machine learning to expedite the solution process of SCUC using mixed-integer programming solvers.

## ■ SC63

West Bldg 103B

### Joint Session DM/Practice Curated: Data Analytics of Complex Data and its Applications

Sponsored: Data Mining

Sponsored Session

Chair: Wanlu Gu, University of Arizona, Tucson, AZ, United States

Co-Chair: Neng Fan, University of Arizona, Tucson, AZ, United States

#### 1 - Parametric Approach for Developing Quick Quotes in Fabrication

Ravi Suman, University of Wisconsin-Madison, Madison, WI, 53726, United States, Omar Habib, Ananth Krishnamurthy, Sushanta Sahu

We describe a methodology to develop rapid and accurate quotes for fabrication jobs. First, fabrication hours are estimated using parametric equations and part drawings. Next, multistep regression model is used to minimize the input features, speed up the estimation process, and derive accurate estimates of pre-weld and post-weld operations. Finally, model coefficients, exponents, and hyperparameters are set using training data. Validation studies using industry data shows that the methodology reduces quoting times by 50% while providing estimates that are within acceptable industry range.

## 2 - A Markov Decision Process to Identify Optimal Policies for Stopping a Trial of Labor

Karen T. Hicklin, University of North Carolina at Chapel Hill, B-24 Hanes Hall, Chapel Hill, NC, 27599-3260, United States, Julie Simmons Ivy

For first time moms the decision to have a cesarean delivery (C-section) can lead to future complications in subsequent pregnancies such as uterine rupture or repeat C-sections. In addition to the health risk associated with C-sections, there is general consensus that the C-section rate in the United States is too high and not associated with a decrease in maternal and neonatal morbidity or mortality. We model the mode of delivery decision using a Markov decision process (MDP). This MDP evaluates when a C-section is optimal as a function of total time spent in labor and the associated rate of complications.

## 3 - Analysis of Aggregate Data using Phase-type Distribution for Reliability Estimation

Samira Karimi, University of Arkansas, Fayetteville, AR, United States, Haitao Liao

One of the most accessible component reliability data in industry is aggregate lifetime data from fielded systems. While Gamma and Inverse Gaussian have been used in reliability estimation using aggregate data, Phase-type (PH) distribution has not been studied in the related literature. In this work, an expectation-maximization (EM) algorithm is proposed to estimate the parameters of PH distribution based on aggregate data. In addition, a Bayesian alternative is also studied and confidence region for model parameters are provided. A numerical study shows the strength of using PH distribution as an alternative for handling aggregate lifetime data.

## 4 - Modeling Patient Flow Information with Covariates using Phase-type Distributions

Wanlu Gu, University of Arizona, Tucson, AZ, 85719, United States, Neng Fan

The hospital length-of-stay (LOS) measures the time from admission to discharge. It demonstrates patient flow and plays an important role in health care quality improvement. In this paper, we fit the Coxian phase-type (PH) distributions to the patient flow information collected in Banner University Medical Center Tucson and assess the effects of covariates, including age, gender, admission type etc. The resulting estimated PH distributions can classify patients into different LOS groups and the pattern under each group is identified. The estimated coefficients and the statistical significance of covariate effects will help decision making in healthcare service and sources assignment.

## ■ SC64

West Bldg 104A

## Joint Session DM/Practice Curated: Data Science and Analytics in Health Care III

Sponsored: Data Mining

Sponsored Session

Chair: Hamidreza Ahady Dolatsara, Auburn University, Auburn, AL

## 1 - Neural Fuzzy-based Unscented Kalman Filter Model for Atrial Fibrillation Onset Prediction

Trung Le, North Dakota State University, Fargo, ND, 58102, United States

Atrial fibrillation is the most common arrhythmia, which increases the risk of stroke by 5 times and potentially leads to embolism. Assessing the risk of developing PAF is important to avoid the risk of death; previous work has only focused on addressing the challenge for predicting the onset of paroxysmal atrial fibrillation (PAF) from the morphological-temporal features of surface electrocardiogram by utilizing machine learning-based techniques. In this paper, we propose a method based on a combination of Kalman filter algorithm and a Neural Fuzzy network to predict PAF onset for 70 patients suffering from PAF.

## 2 - Quantification of Stroke Risk in Patients with Atrial Fibrillation and Obstructive Sleep Apnea

Rupesh Kumar Agrawal, Research Assistant, Oklahoma State University, Tulsa, OK, 74106, United States, Daniel Tran, Matt Wilkett, Dursun Delen, Bruce Benjamin

Extant research work has established strong correlation in patients with Atrial Fibrillation (A-Fib), the Obstructive Sleep Apnea (OSA) and the increased risk of stroke. CHADS2 and CHA2DS2-VASc scores are used to calculate the risk of stroke based on circulatory and respiratory mechanism. This is a pilot study to quantify stroke risk in patients with A-Fib, OSA, to show that the stroke risk is higher in patients, independent of treatment with anticoagulants used to treat patients with A-Fib. Furthermore, our goal is also to develop human subject clinical trial, based on the knowledge gained from the analytics study to develop a score for OSA as part of the criteria for calculating a risk of stroke

## 3 - Quantifying the Motivation of Physicians' Continuous Charitable Clinics Choice Online

Han Yang, Beijing Institute of Technology, No.5 Zhongguancun South Street, Haidian Dist, Beijing, 100081, China, Zhijun Yan, Lun Li

Online healthcare communities is a novel channel for physicians to share healthcare knowledge with patients. The services that physicians provide in OHCs consist of paid health services and charitable clinics services, and we have limited knowledge on the motivation of physicians' continuous charitable clinics choice online. We develop a logistic model to examine three types of motivation of physicians' continuous charitable clinics choice, including economic, social image and altruistic motivation. Based on the data from Guahao.com, we find that different types of motivation has different effects on physicians' continuous charitable clinic behavior based on different situations.

## ■ SC65

West Bldg 104B

## Big Data, Economic Modeling, and Reliability

Sponsored: Data Mining

Sponsored Session

Chair: Kezban Yagci Sokat, Northwestern University, IEMS, 2145 Sheridan Rd, Evanston, IL, 60208, United States

## 1 - Influencing Donation Choice in Social Networks after Disasters

Trilce Encarnacion, Rensselaer Polytechnic Institute, 110 8th Street, Jonsson Engineering Center # 4049, Troy, NY, 12180, United States

The goal of this research is to develop analytical methods to effectively influence donation choice in a social network setting. To do so, several objectives need to be accomplished: a) Develop a network influence model formulation to represent the social network interactions b) Incorporate behavior research regarding individuals attitudes and socio-economic characteristics in relationship to donation behavior; c) Develop a diffusion model to characterize influence propagation through the social network after a disaster occurs; and, d) Select an appropriate influencing strategy to effect change in donation choice.

## 2 - Predicting Major Stock Indices using Macroeconomic Indicators

Lin Lu, Auburn University, Auburn, AL, 36830, United States, Waldyn Martinez, Bin Weng, Fadel Mounir Megahed

This paper proposes a two-stage approach to investigate whether macroeconomics variables alone can be used to accurately predict the one-month ahead price for major U.S. stock and sector indices. Stage 1 evaluates the hypothesis that the price for different indices is driven by different economic indicators. Stage 2 uses a hybrid approach of the recurring neural network and the ensembles models to examine the secondary hypothesis that residuals from the time-series model are not random and can be explained by incorporating macroeconomic indicators through the ensemble approach. Results showed that the macroeconomic indicators are leading predictors of the price of 13 U.S. sector indices.

## 3 - Reliability Estimation for Balanced Systems with Multi-dimensional Distributed Units

Elsayed A. Elsayed, Distinguished Professor, Rutgers University, Department of Industrial and Systems Eng, 96 Frelinghuysen Road, Piscataway, NJ, 08854, United States, Jingbo Guo

Balanced systems with multi-dimensional distributed units are emerging in a diverse range of industries. For example, Unmanned Aerial Vehicle (UAV) with multi-layer of rotary wings and spherical UAVs are used in many applications due to their stability and flexibility. A minimum number of units is required to function properly in a balanced arrangement for the system to operate properly. Reliability estimation for such complex systems is studied under different conditions.

## 4 - A Note on Pricing Model of ESG Investing

Hiroshi Ishijima, Chuo University, 42-8 Ichigaya-honmura-cho, Shinjuku, Tokyo, 1628473, Japan, Akira Maeda

Modern investors have been paying more attention to ESG investing than ever which is defined as the consideration of environmental, social and governance factors as well as the conventional finance factor regarded as the discounted sum of future cash flows. Along these lines, we would like to develop a rational pricing model of ESG investing. We then conduct a preliminary empirical analysis in the Japanese stock market to show whether ESG investing is profitable enough to compensate for fiduciary duties as stated in the Principles for Responsible Investment.

## 5 - Modelling Human Trafficking

Kezban Yagci Sokat, Northwestern University, IEMS, 2145 Sheridan Rd, Evanston, IL, 60208, United States, Nezh Altay

Human trafficking has become a serious concern for society and the global economy. While there has been a lot of attention in this topic in the social contexts, there is little in the humanitarian operations community. We develop a model for human trafficking and study the impact of relevant law.

## ■ SC66

West Bldg 105A

### Business Value of Artificial Intelligence

Sponsored: Artificial Intelligence

Sponsored Session

Chair: Zhongju Zhang, Arizona State University, Tempe, AZ, 85287, United States

#### 1 - Social Learning in Prosumption: Evidence from a Randomized Field Experiment

Tianshu Sun, University of Southern California, 3670 Trousdale Parkway, Bridge Hall, BRI 310B, Los Angeles, CA, 90089, United States, JaeHwuen Jung, Ravi Bapna, Joseph Golden

A customer can now actively participate in the design for a wide range of products, as a 'prosumer'. However, a major challenge in prosumption is the effort involved and ideas required. We combine a randomized experiment with machine learning to examine whether social learning, the act of showing the focal user creations made by other users, can improve users' project creation and purchase decision. We find that under certain conditions, showing other users' design can be highly effective. We further explore heterogeneity in treatment effect across image and user characteristics and find that three types of social learning mechanisms - idea learning, product learning, and self-efficacy - are at play.

#### 2 - High-order Proximity Preserving Information Network Hashing

Yong Ge, University of Arizona, 5776 S.Tiger Lily PL, Tucson, AZ, 85747, United States

Information network embedding is an effective way for efficient graph analytics. We propose a MF-based Information Network Hashing (INH-MF) algorithm, to learn binary codes which can preserve high-order proximity. We also suggest Hamming subspace learning, which only updates partial binary codes each time, to scale up INH-MF. We finally evaluate INH-MF on four real-world information network datasets with respect to the tasks of node classification and node recommendation. The results demonstrate that INH-MF can perform significantly better than competing learning to hash methods in both tasks, and surprisingly outperforms network embedding methods

#### 3 - Crowdboosting: A Boosting-based Model for Crowd Opinions Aggregation

Qianzhou Du, Virginia Tech, Blacksburg, VA, 24060, United States, Alan Gang Wang, Weiguo Fan

Most existing crowd opinion aggregation studies employ rules to determine a weighting scheme for judges based on their past prediction performance. However, those rule-based methods often fail to determine the optimal weights and achieve the optimal prediction performance. We propose a new crowd opinion aggregation model, namely CrowdBoosting, which has a combining procedure for converting weak learners to strong ones and a mechanism of estimating the probabilities of event outcomes based on statistical learning. We empirically evaluate CrowdBoosting in comparison to four baseline methods. The results show that CrowdBoosting significantly outperforms all the baseline methods.

#### 4 - Towards Better Learning from Crowd Labeling

Junming Yin, University of Arizona, Management Information Systems Department, McClelland Hall, Room 430BB, Tucson, AZ, 85721, United States

Microtask crowdsourcing has emerged as a cost-effective approach to obtaining large-scale labeled data in a wide range of applications. Crowdsourcing platforms such as MTurk and CrowdFlower provide an online marketplace where task requesters can submit a batch of microtasks, which a crowd of workers can then complete for a small monetary compensation. However, as the information provided by crowd workers can be prone to errors, significant effort is required to infer the true labels from such noisy labels supplied by a set of heterogeneous workers. Moreover, it would be very beneficial to identify (and then possibly filter out) those crowd workers with low reliabilities so as to foster the creation of a healthy and sustainable crowdsourcing ecosystem. Existing literature on learning from crowds has mainly focused on the single-label (i.e., binary and multi-class) setting, which prevents the application of microtask crowdsourcing to a wide range of business applications in which each item can be associated with multiple labels simultaneously. In this work, we consider the problem of learning from crowd labeling in the general multi-label setting, which includes previously studied single-label crowdsourcing problems as special cases. We propose a new Bayesian hierarchical model for the underlying annotation process of crowd workers, and introduce a mixture of Bernoulli distribution to capture the unknown label dependency. An efficient variational inference procedure is then developed to jointly infer ground truth labels, worker reliability in terms of sensitivity and specificity, and label dependency. Results based on extensive simulation experiments and a real-world MTurk experiment indeed confirm that the proposed approach outperforms other competing methods, highlighting the necessity to model both worker quality and label dependency when learning from crowdsourced multi-label annotations.

## ■ SC67

West Bldg 105B

### Economics of IS

Sponsored: Information Systems

Sponsored Session

Chair: Jingjing Li, University of Virginia

#### 1 - An Empirical Evidence of Price Dispersion in Electronic Markets

Jin Sik Kim, University of California-Irvine, 5102 Palo Verde Road, Irvine, CA, 92617, United States, Vijay C. Gurbaxani

Theory predicts that the price of comparable product at online retailers would exhibit low price dispersion; yet, there is empirical evidence to the contrary. This paper investigates online price dispersion in two product types. We hypothesize that product types may influence price dispersion differently because of uncertainty to customers. Seller information may play a vital role in forming dispersed price. Lastly, we assume that search costs may lead to price dispersion. Our logistic regression results show the product with high uncertainty lead to higher price dispersion, some of the seller information increases price dispersion, and search costs are positively related to price dispersion.

#### 2 - Are More Diverse Crowds Smarter?

Jiayu Yao, Georgia Institute of Technology, Atlanta, GA, United States, Qiang Gao, Mingfeng Lin

Does the diversity increase the wisdom of crowds? We examine the value of diversity in crowds within a market setting, specifically, the online financial market, utilizing a natural experiment on Prosper.com.

#### 3 - Personalized Recommendations and Platform Monetization: Theory and Evidence from an App Portal

Shengjun Mao, University of California-Irvine, Paul Merage School of Business SB1 3300, University of California, Irvine, Irvine, CA, 92697, United States, Sanjeev Dewan, Yi-Jen (Ian) Ho

We examine app monetization on a mobile portal. Specifically, we study the click and conversion performance as a function of screen rank, app popularity, and app quality. We also apply natural language processing to investigate the app titles and descriptions in terms of the ambiguity, informativeness, and sentiment. We develop a bivariate probit model to jointly analyze click and conversion choices using a hierarchical Bayesian approach. Our results not only confirm the effects of ranking, popularity and quality but show the subjective text information matters. More importantly, our analyses help optimize the app placements to maximize the profits of the portal through personalization.

## ■ SC68

West Bldg 105C

### Technometrics Invited Session

Sponsored: Quality, Statistics and Reliability

Sponsored Session

Chair: Alaa Elwany, Texas A&M University, College Station, TX, 77843, United States

Co-Chair: Xiao Liu

Co-Chair: Daniel Apley, Northwestern University, Evanston, IL, 60208-3119, United States

#### 1 - Bayesian Model Building from Small Samples of Disparate Data for Capturing In-plane Deviation in Additive Manufacturing

Arman Sabbaghi, Purdue University, 150 N. University Street, West Lafayette, IN, 47907, United States, Qiang Huang, Tirthankar Dasgupta

Quality control of shape deviation in additive manufacturing relies on statistical deviation models. However, resource constraints limit the manufacture of test shapes, and consequently impede the specification of models for new shapes. We present an adaptive Bayesian methodology that effectively combines in-plane deviation data and models for a small sample of previously manufactured, disparate shapes to aid in the model specification of in-plane deviation for new shapes. The power and simplicity of this method is demonstrated with case studies on in-plane deviation modeling for polygons and straight edges in free-form shapes using only data and models for cylinders and a single pentagon.



**2 - Degradation in Common Dynamic Environments**

Zhi-Sheng Ye, National University of Singapore, E1-07-26  
Computing lab, 10 Kent Ridge Road, Singapore, 119260,  
Singapore, Qingqing Zhai

Degradation studies are useful for reliability evaluation. Because of limited test resources, several test subjects may have to share a test rig. The common environments experienced by subjects in the same group introduce significant inter-individual correlations in their degradation. In the study, the Wiener process is used to model product degradation, and the group-specific random environments are captured using a stochastic time scale. Both semiparametric and parametric estimation procedures are developed for the model. Performance of the maximum likelihood estimators is validated theoretically and by simulation. The proposed models are illustrated by an application to LED data.

**3 - A Nonparametric Adaptive Sampling Strategy for Online Monitoring of Big Data Streams**

Xiaochen Xian, Madison, WI, 53705, United States, Andi Wang,  
Kaibo Liu

With the rapid advancement of sensor technology, a huge amount of data is generated in various applications, which poses new and unique challenges for Statistical Process Control (SPC). In this paper, we propose a Nonparametric Adaptive Sampling (NAS) strategy to online monitor non-normal big data streams in the context of limited resources, where only a subset of observations are available at each acquisition time. In particular, the proposed method integrates a rank-based CUSUM scheme and an innovative idea that corrects the anti-rank statistics with partial observations, which can effectively detect a wide range of possible mean shifts when data streams follow arbitrary distributions.

**■ SC69**

West Bldg 106A

**Joint Session QSR/Practice Curated: QSR Student Interaction Session**

Sponsored: Quality, Statistics and Reliability

Sponsored Session

Chair: Dongping Du, Texas Tech University, Lubbock, TX, 79409, United States

Co-Chair: Raed Al Kontar

**1 - QSR Student Interaction Session**

Dongping Du, Texas Tech University, 2500 Broadway,  
P.O. Box 43061, Lubbock, TX, 79409, United States

The Student Interaction Session is designed for QSR student to build their professional network, show up their talents, and learn from invited guests. The session consists of students' introduction, student and guest interactions, and Best Student Poster Competition. Each participant will have 2 minutes to deliver an elevator speech about his/her research interests and accomplishments; Senior QSR members and guests will be invited to interact with attendees and share experience; A panel of judges will select a poster competition winner, which will be announced at the QSR business meeting.

**■ SC70**

West Bldg 106B

**Joint Session QSR/DM/Public Sector: Functional, Image and Shape Data Analysis; Methodology and Applications**

Sponsored: Quality, Statistics and Reliability

Sponsored Session

Chair: Hao Yan, Tempe, AZ, 85281, United States

Co-Chair: Kamran Paynabar, Georgia Institute of Technology,  
Atlanta, GA, 30332-0205, United States

**1 - Online Monitoring for Metal Based Additive Manufacturing Processes using a Dual Control Charting System Based Thermal Image Tensor Decomposition**

Mojtaba Khanzadeh, Mississippi State University, Starkville, MS,  
39759, United States, Linkan Bian, Wenmeng Tian

Real-time thermal image streams captured from AM processes are regarded as most informative signatures of the process stability. The objective of this paper is to develop a statistical process control to detect process changes based on predefined distribution of the monitoring statistics. There are two major challenges: Complex spatial interdependence exists in the thermal images; the thermal images suffer from a large data volume and low signal-to-noise ratio. Multilinear principal component analysis approach is used to extract low dimensional features and residuals. Subsequently, an online dual control charting system is proposed by leveraging multivariate  $T^2$  and Q control charts.

**2 - Lifetime Prediction of Condition Monitoring Signals using Monotonic B-splines with Infinite Support**

Salman Jahani, University of Wisconsin-Madison, Department of Industrial/Systems Engineering, 1513 University Avenue,  
Madison, WI, 53706, United States, Raed Kontar, Shiyu Zhou,  
Dharmaraj Veeramani

Most sensor-based condition monitoring signals in practice are not observed after the failure threshold which results in truncated signals and are subject to high level of noise. This study claims a mixed effects model based on B-splines of infinite support procedure to account for truncation and noise using extrapolation feature and monotonicity conditions of B-splines with infinite support. The performance of the proposed procedure is further investigated through analysis based on the numerical studies and case study with real world data from automotive lead acid batteries.

**3 - Time-warped Sparse Representation for Nonnegative Functional Data Analysis**

Chen Zhang, Tsinghua University, Beijing, 100084, China

This paper proposes a novel framework for learning time-warped sparse non-negative factorization of functional data. The proposed method not only can guarantee the extracted bases and their coefficients to be positive and interpretable, but also can handle weakly correlated functions with different features. Furthermore, the proposed method incorporates time warping into feature learning, and allows the bases of different samples to have temporal deformations. To solve the learning task, we propose an efficient framework of estimation algorithms based on a greedy variable selection approach.

**4 - Machine Annotation of Post-hurricane Satellite Imagery for Identifying Damages**

Quoc Dung Cao, University of Washington, Seattle, WA,  
United States

After a hurricane makes a landfall, emergency managers and first responders commonly assess the damage by driving around the impacted area (also known as a windshield survey). Recently, post-event images captured by satellites started to facilitate the damage assessment, but the process still largely relies on human visual inspection. To improve the efficiency and accuracy of damage assessment, we propose to automatically label damages using image classification techniques. The method is applied to the case study of 2017 Hurricane Harvey.

**■ SC71**

West Bldg 106C

**Joint Session ICS/Practice Curated: Decomposition Algorithms for Power Grid Optimization**

Sponsored: Computing

Sponsored Session

Chair: Deepak Rajan, Lawrence Livermore National Laboratory,  
Livermore, CA, 94551, United States

**1 - Optimizing Power System Restoration using Mixed Integer Linear Programming**

Ignacio Aravena, Universite Catholique de Louvain, Voie du Roman Pays 34, Center for Operations Research and Econometrie,  
Louvain-la-Neuve, B-1348, Belgium, Deepak Rajan,  
Georgios Patsakis, Jennifer Rios, Shmuel S. Oren

We present a novel framework for optimizing power system restoration and black-start allocation as MILPs. First, we build piece-wise linear approximations of power flow equations that account for the regime of excess of reactive power typical during restoration. Then, we propose a specialized integer L-shaped algorithm that decouples the power flow equations from the combinatorial dynamics of the restoration process. The method allows sharing cuts between time periods and formulating feasibility cuts over electrical islands. We present numerical results for modified IEEE test systems and models of the WECC and the Chilean power grids demonstrating the effectiveness of the proposed approach.

**2 - Scalable Decomposition for Stochastic Unit Commitment**

Jean-Paul Watson, Sandia National Laboratories, 7305 Blue  
Cypress Avenue NE, Albuquerque, NM, 87113-2065,  
United States, David L. Woodruff, Bernard Kneuev

We discuss recent advances in scenario-based decomposition algorithms for solving realistic, large-scale stochastic unit commitment problems. We focus on mitigating the difficulty of instances with diverse renewables production patterns, which can cause serious degeneration in practical convergence behaviors. Mitigation proceeds through the use of cross-scenario cuts. We will discuss experimental results and newly created openly available benchmarks.

### 3 - Parallel Temporal Decomposition Method for Long-term Unit Commitment Problems

Kibaek Kim, Argonne National Laboratory, 9700 South Cass Avenue, Building 240, Lemont, IL, 60439, United States, Audun Botterud, Feng Qiu

We consider a long-term unit commitment (UC) for power system production cost modeling. The UC problem is formulated as a large-scale mixed-binary linear programming problem. We present the Lagrangian dual decomposition method that solves the long-term UC by decoupling the long-term horizon into several sub-horizons. We also develop the branch-and-bound method on top of the dual decomposition, which enables to find a global optimal solution. The method has been implemented in an open-source optimization framework DSP that can run in parallel on high-performance computing clusters. In our computational experiments, we show significant reductions in solution time as compared with CPLEX.

### 4 - ADMM for SCUC: Effects of Market Characteristics and Subproblem Design on Algorithm Performance

Jesse Holzer, Pacific Northwest National Laboratory, 902 Battelle Blvd, Richland, WA, 99354, United States, Feng Pan, Yonghong Chen, Stephen Elbert

Security constrained unit commitment (SCUC) is the computational engine for day ahead wholesale electricity markets. As markets evolve, larger networks and numerous smaller energy resources pose increasing computational challenges for mixed integer programming (MIP) solvers. The alternating direction method of multipliers (ADMM) has been applied to SCUC as a scalable alternative to MIP. ADMM has guaranteed convergence in convex problems, but SCUC is nonconvex. We compare ADMM and MIP on large scale instances, observing that smaller and more numerous resources and larger subsystems tend to improve ADMM convergence but make the subproblems more expensive.

## ■ SC72

West Bldg 211A

### Nicholson Student Paper Competition II

Emerging Topic: Nicholson Student Paper Prize

Emerging Topic Session

Chair: John Hasenbein, University of Texas-Austin, 1 University Station Stop C2200, Department of Mechanical Engineering, Austin, TX, 78712-0292, United States

Chair: Phebe Vayanos, University of Southern California, OHE 310L, University Park Campus, USC, Viterbi School of Engineering, Los Angeles, CA, 90089, United States

### 1 - Synthesis and Generalization of Structural Results in Inventory Management: A Generalized Convexity Property

Zhe Liu, Columbia University, New York, NY, USA, Awi Federgruen

We address a general periodic review inventory control model with the simultaneous presence of the following complications: (a) bilateral inventory adjustment options, via procurement orders and salvage sales or returns to the supplier; (b) fixed costs associated with procurement orders and downward inventory adjustments (via salvage sales or returns); and (c) capacity limits associated with upward or downward inventory adjustments. We provide a full characterization of the optimal procurement strategy, both for finite and infinite horizon periodic review models, by showing that in each period the inventory position line is to be partitioned into (maximally) five regions. Our results are obtained by identifying a novel generalized convexity property for the value functions, which we refer to as strong (C1K1, C2K2)-convexity. To our knowledge, we recover almost all existing structural results for models with exogenous demands as special cases of a unified analysis.

### 2 - Small-loss Bounds for Online Learning with Partial Information

Thodoris Lykouris, Cornell University, Ithaca, NY, USA.

We consider the problem of adversarial (non-stochastic) online learning with partial information feedback, where at each round, a decision maker selects an action from a finite set of alternatives. We develop a black-box approach for such problems where the learner observes as feedback only losses of a subset of the actions that includes the selected action. When losses of actions are non-negative, under the graph-based feedback model introduced by Mannor and Shamir, we offer algorithms that attain the so called “small-loss”  $\alpha(L?)$  regret bounds with high probability, where  $\alpha$  is the independence number of the graph, and  $L?$  is the loss of the best action. Prior to our work, there was no data-dependent guarantee for general feedback graphs even for pseudo-regret (without dependence on the number of actions, i.e. utilizing the increased information feedback). Taking advantage of the black-box nature of our technique, we extend our results to many other applications such as semi-bandits (including routing in networks),

contextual bandits (even with an infinite comparator class), as well as learning with slowly changing comparators. In the special case of classical bandit and semi-bandit problems, we provide optimal small-loss, high-probability guarantees of  $e O(\sqrt{dL?})$  for actual regret, where  $d$  is the number of actions, answering open questions of Neu. Previous bounds for bandits and semi-bandits were known only for pseudo-regret and only in expectation. We also offer an optimal  $e O(\sqrt{L?})$  regret guarantee for fixed feedback graphs with clique-partition number at most  $\alpha$ .

### 3 - Distributionally Robust Inverse Covariance Estimation: The Wasserstein Shrinkage Estimator

Daniel Kuhn, Ecole Polytechnique Federale de Lausanne (EPFL), Lausanne, Switzerland, Viet Anh Nguyen.

We introduce a distributionally robust maximum likelihood estimation model with a Wasserstein ambiguity set to infer the inverse covariance matrix of a  $p$ -dimensional Gaussian random vector from  $n$  independent samples. The proposed model minimizes the worst case (maximum) of Stein's loss across all normal reference distributions within a prescribed Wasserstein distance from the normal distribution characterized by the sample mean and the sample covariance matrix. We prove that this estimation problem is equivalent to a semidefinite program that is tractable in theory but beyond the reach of general purpose solvers for practically relevant problem dimensions  $p$ . In the absence of any prior structural information, the estimation problem has an analytical solution that is naturally interpreted as a nonlinear shrinkage estimator. Besides being invertible and well conditioned even for  $p > n$ , the new shrinkage estimator is rotation-equivariant and preserves the order of the eigenvalues of the sample covariance matrix. These desirable properties are not imposed ad hoc but emerge naturally from the underlying distributionally robust optimization model.

### 4 - Data-Driven Personalized Decision Making: Algorithm, Theory and Application

Zhengyuan Zhou, Stanford University, Stanford, CA, USA.

In this paper, we study the general online policy learning problem where we aim to learn an effective policy from observational datasets. We propose a novel learning algorithm and establish that it achieves the (asymptotically) optimal regret guarantee, thereby settling the open problem of which learning algorithm to choose in this context. To the best of our knowledge, this is the first provably optimal learning algorithm in the general online policy learning problem and provides a substantial performance improvement over all the existing learning algorithms. We also additionally investigate the application aspects of policy learning by working with finite-depth trees, a specific policy class that is widely used as decision rules in practice. We formulate a key step of the learning algorithm as a mixed integer program, which enables us to solve it to exact optimality. Together, these results contribute to the broad landscape of data science by providing a state-of-the-art personalized decision making framework that is optimal in both generalization and optimization.

## ■ SC73

West Bldg 211B

### JFIG Paper Competition II

Sponsored: Junior Faculty JFIG

Sponsored Session

Chair: Oleg Prokopyev, University of Pittsburgh, 1031 Benedum Hall, Pittsburgh, PA, 15261, United States

Co-Chair: Fatma Kilinc Karzan, Carnegie Mellon University, Pittsburgh, PA, 15217, United States

### 1- JFIG Paper Competition

Oleg Prokopyev, University of Pittsburgh, Pittsburgh, PA, USA,

The 2018 JFIG paper competition features paper submissions from a diverse array of talented junior faculty members. The prize committee evaluated submissions based on the importance of the topic, appropriateness of the approach, and significance of the contribution. After careful review, the prize committee selected a group of finalists to present their research in one of the two JFIG sessions. For information on the finalists and their papers, please refer to the online program..

## ■ SC74

West Bldg 212A

**Joint Session MCDM/Practice Curated: MCDM in Practice**

Sponsored: Multiple Criteria Decision Making

Sponsored Session

Chair: Lorraine Gardiner, Dalton State College

**1 - Multi-Objective Delivery Allocation**

Jonathon Leverenz, Systems Planning and Analysis, Inc,  
Alexandria, VA, 22302, United States, Stephanie Diane Brown,  
Chris Grubb

The Multi-Objective Delivery Allocation problem assigns delivery vehicles to jobs delivering equipment to a set of locations. Each vehicle is assigned a job and each job contains multiple locations. Locations can be assigned to multiple jobs and grouped together in various ways resulting in multiple options for each vehicle. Vehicle-location pairs are assigned a probability representing the chance of a successful delivery. Assignments are made under competing objectives that include cost, location coverage, probability of success, and expected number of completed deliveries. A network-with-gains model is used to make assignments and investigate tradeoffs between the various objectives.

**2 - Blockchain's Impact on Digital Supply Chain: Contributions from MCDM**

Birsen Karpak, Distinguished Professor, Youngstown State  
University, One University Plaza, WCBA 3303, Youngstown, OH,  
44555, United States, Valerio A. Salomon

Digital Supply Chain (DSC) is about the way how supply chain processes are managed with a wide variety of innovative technologies, e.g. internet of things, big data, cloud computing, among others. Blockchain is the new-comer not explored even in the frameworks offered very recently. This study explores the impact of blockchain on digital supply chain and reports the findings of the implementation of a proposed DSC framework into an industrial real-case. Authors see a potential contribution from multiple criteria decision approaches.

**3 - Weighting Criteria for Agriculture Planning: An Application of the Analytical Hierarchy Process**

Jay Parsons, University of Nebraska-Lincoln, 103B Filley Hall,  
P.O. Box 830922, Lincoln, NE, 68583-0922, United States,  
Kathleen Brooks

A statewide farm financial health survey of Nebraska farmers and ranchers was conducted in 2016 to assess farm and ranch financial stress as a result of low commodity prices. In the survey, producers were asked a series of questions to assess the importance of different factors in their planning process. The analytical hierarchy process is used to identify the importance of the factor criteria for all respondents as a whole and for various segments of the sample population.

**4 - Survey on the Practice and Implementation of MCDM**

Lorraine R. Gardiner, Dalton State College, Wright School of  
Business, 650 College Drive, Dalton, GA, 30720, United States

The purpose of the research survey is to document and classify published accounts describing the practice of MCDM. The survey includes peer-reviewed articles that describe the actual use of one or more MCDM methods by decision makers in an organization. The author summarizes results by general problem area, organizational type, decision level, degree of organizational involvement and MCDM method category.

## ■ SC75

West Bldg 212B

**Service-oriented Enterprise Analysis**

Sponsored: Military and Security

Sponsored Session

Chair: Mark Gallagher, US Air Force, Arlington, VA, United States,

**1 - Strategy-to-Task Hierarchy for a Strategy through System Requirements Framework**

Mark Gallagher, US Air Force, Arlington, VA, United States,  
Michael Moss, Doug Fullingim

The Air Force Warfighting Center (AFWIC) is developing a functional linkage that maps strategy themes through our concept documents to our capabilities and systems. This framework enables us to justify requirements in terms of achieving the strategy and concepts that are driving them. We present the current version of this strategy-to-task framework.

**2 - Air Force Warfighting Integration Center (AFWIC) Analyses**

Mark Gallagher, US Air Force, Arlington, VA, United States,  
Doug Fullingim

The Air Force has established an Air Force Warfighting Integration Center (AFWIC) to "drive innovation and transformation to ensure the AF provides the world's most ready, lethal, and dominant air force to the joint fight. We discuss the steps between strategy and budget, and how we are using wargaming, analyses, and assessments to support the decisions at each of those steps. Much of our analytical challenges are modeling the concepts and ideas impact on future warfare integrated view.

**3 - A New Framework for Naval Inventory Models**

Javier Salmeron, Naval Postgraduate School, 1411 Cunningham  
Road, Monterey, CA, 93943, United States, Duncan Ellis

Naval Supply Systems Command, Weapons Systems Support sets inventory policy across all echelons of supply. In 2014, it partnered with the Naval Postgraduate School to develop an in-house suite of inventory models: Wholesale Inventory Optimization Model, currently in production; Site Level Inventory Optimization Model, sets reorder points and quantities at Naval Air Stations and Distribution Depots; Naval Aviation Readiness Based Sparing Model, sets inventory levels for aviation weapon systems to achieve operational availability. The models introduce novel features, provide defensible, auditable, and transparent policy, and help to maintain critical skills within the civil service.

**4 - A Comparative Assessment of Network Solution Methodologies for the Comprehensive Core Capability Risk Assessment Framework**

Alex M. Marshall, Analyst, The Perduco Group, 3610 Pentagon  
Blvd, Suite 110, Beavercreek, OH, 45431, United States,  
Paul F. Auclair

Given an enterprise-level risk model consisting of a weighted, directed, cyclic network, we describe an experimental approach to examining the suitability of four network solution methods for estimating the effect of risk propagating across the network. We also compare results obtained from detailed activity-level networks to those obtained from aggregated capability-level networks and suggest adjustments to eliminate observed aggregation bias and divergence from notional composite truth solutions.

## ■ SC76

West Bldg 212C

**Performance Modeling and Optimization in Manufacturing Systems**

General Session

Chair: James M. Smith, University of Massachusetts-Amherst, Amherst, MA, 01002, United States

**1 - Scheduling Policies in Flexible Bernoulli Lines with Dedicated Finite Buffers**

Jingshan Li, University of Wisconsin-Madison, 1513 University  
Avenue, 3222 Mechanical Engineering Building, Madison, WI,  
53706, United States, Kyungsu Park, Shaw Feng

This presentation is devoted to studying scheduling policies in flexible serial lines with two Bernoulli machines and dedicated finite buffers. Priority, cyclic and work-in-process (WIP)-based scheduling policies are investigated.

**2 - Stochastic Models for Multi-resource Allocation in Biomanufacturing**

Yasemin Limon, University of Wisconsin-Madison, Madison, WI,  
53705, United States, Ananth Krishnamurthy

We analyze multi-resource allocation decisions for protein purification projects that need to meet strict yield and purity requirements. The purification project can involve multiple steps, each step improving the purity of the sample, although resulting in some yield loss in the process. These purification projects are completed by scientists with different capabilities and capacities. We analyze allocation strategies of projects to scientists using queueing models. Exact solutions are obtained by applying Matrix-Geometric solution algorithms and numerical examples are presented to explore the impact of different strategies on the system performance.

**3 - A Branch and Bound Procedure for Chance Constrained Stochastic Assembly Line Balancing**

Raik Stolletz, PhD, University of Mannheim, Mannheim,  
Germany, Johannes Schnitzler

We analyze the assembly line balancing problem where tasks have to be assigned to stations with the goal of minimizing the number of stations used. Task times are stochastic, leading to the possibility of incomplete work pieces. Therefore, we consider a constraint on the probability of finishing a work piece within the given cycle time. A sampling model is developed to account for generally distributed task times. We present a bidirectional branch and bound procedure in order to solve the model. A numerical study compares the performance of the algorithm to the solution with standard solvers.



**4 - Multifidelity Models for Buffer Allocation Problems**

Andrea Matta, Politecnico di Milano, Via La Masa 1, Milan, 20156, Italy, Ziwei Lin, Nicla Frigerio

Buffer allocation problems in flow line require the estimation of the expected throughput of the system. Literature reports a rich set of optimization methods using either analytical methods or discrete event simulation as performance evaluation models. The two kinds of models are usually used sequentially at different levels of the optimization phase. This work explores the advantages and drawbacks of combining them into the buffer allocation problem. Different multifidelity regression models are used as surrogate models for estimating the expected system throughput in the buffer allocation problem. Results show that using low fidelity models helps to reduce the total computational effort.

**5 - Simultaneous Optimization of Buffer Allocation, Routing, & Population in Closed Finite Queueing Networks**

James Smith, University of Massachusetts at Amherst, MA, United States, Sencer Yeralan

Optimal routing in closed finite queueing networks is a challenging problem all by itself. When it is combined with optimal buffer allocation and the population of the closed network, we achieve a mixed integer nonlinear programming problem. A queueing performance decomposition approach combined with a sequential quadratic programming algorithm is the main vehicle for the analysis and synthesis of the problem. Various closed network topologies are utilized to demonstrate the efficacy of the methodology.

**■ SC77**

West Bldg 213A

**Decision Analytic Models at the Centers for Disease Control and Prevention**

Sponsored: Public Sector OR

Sponsored Session

Chair: Chaitra Gopalappa, University of Massachusetts, Amherst, MA, 01003, United States

Co-Chair: Seyedeh Khatami

**1 - Estimating HIV Transmission Rates Along the HIV Care Continuum in the United States**

Zihao Li, Centers for Disease Control and Prevention, Atlanta, GA, United States, Yao-Hsuan Chen, Chaitra Gopalappa, Paul Farnham, Stephanie Sansom

Estimating HIV transmission rates is critical to understanding how to reduce disease spread. We used the Progression and Transmission of HIV (PATH), an agent-based model that replicates HIV transmission in the United States, to estimate 2015 transmission rates among persons at various stages of HIV care. The overall transmission rate in 2015 was 3.51 per 100 person-years. The rate was 0.07 per 100 person-years for persons in care and virally suppressed compared with 15.64 per 100 person-years for persons newly infected and undiagnosed. Viral suppression is associated with greatly reduced transmission. Thus, strategies to promote viral suppression may be very effective.

**2 - Marginal Cost-effectiveness of Pre-exposure Prophylaxis Compared with Improving HIV Care and Treatment in the United States**

Nidhi Khurana, CDC, 1600 Clifton Road MS E-48, Atlanta, GA, 30333, United States, Paul G. Farnham, Katherine A. Hicks, Justin Carrico, Stephanie L. Sansom

We used a dynamic, compartmental model of the sexually active U.S. population to estimate the marginal cost-effectiveness of preventing HIV infection with pre-exposure prophylaxis (PrEP) compared with preventing HIV transmission through enhanced care and treatment of persons with HIV. We modeled the application of PrEP to persons at high risk of acquiring HIV and investigated its marginal cost-effectiveness for the entire population as well as for individual transmission groups (men who have sex with men, persons who inject drugs, and heterosexuals). We assessed cumulative costs, new infections, and quality-adjusted life-years from 2016 through 2020.

**3 - Using System Dynamics to Investigate HIV Positive Testing Yield in Malawi**

Roma Bhatkoti, CDC, Atlanta, GA, United States, Andrew Auld, Mtemwa K. Nyangulu, George Bicego

With the goal of ending the AIDS epidemic by 2030, UNAIDS set an ambitious target of diagnosing 90% of people living with HIV by 2020 as part of their 90-90-90 framework. As HIV testing programs have expanded over the past few years to meet this target, it has been observed that HIV positive diagnostic yield (a critical factor for determining HIV testing targets) has decreased over time. In order to investigate this declining HIV diagnostic yield and to identify ways to potentially optimize HIV testing strategies, a simulation model was constructed using system dynamics depicting different population stocks. Publicly available data from UNAIDS and the Malawi HIV testing program were used to model yield.

**4 - How to Reach Zero HIV Incidence in the US? A Reinforcement Learning Approach to Optimizing HIV Intervention Decisions**

Seyedeh Khatami, University of Massachusetts Amherst, Amherst, MA, United States

HIV has been a persistent issue in the US. The National HIV/AIDS Strategy (NHAS) for the United States aims to reduce HIV incidence by 25%, by 2020, by increasing coverage on all key interventions that are independently evaluated to be cost-effective. Due to interactions between interventions and the dynamic changes in the epidemic over time, we propose to identify combinations of interventions that can optimally lead to zero incidence, formulated as a sequential decision-making problem. We formulate the problem as a Markov decision process (MDP) with multiple decision stages over a finite time horizon and solve using reinforcement learning, a simulation-based control optimization algorithm.

**■ SC78**

West Bldg 213B

**Location Models**

Sponsored: Location Analysis

Sponsored Session

Chair: Oded Berman, University of Toronto, Toronto, ON, M5S 3E6, Canada

Co-Chair: Dmitry Krass, University of Toronto, Toronto, ON, M5S 3E6, Canada

**1 - Benefit Maximizing Network Design in the Public Sector**

Robert Aboulian, California State University-San Marcos, 2771 Palmetto Drive, Carlsbad, CA, 92009, United States, Oded Berman

Governments are involved in providing essential services, such as healthcare, transportation, education and utilities. Their mandate is to maximize the societal benefit by acting as agents of the public in contrast with the private firms' mission to maximize profit. Many models in this area try to (re-)design the public service so as to maximize the number of people who will benefit from the program given a limited budget. These models do not consider the marginal benefit (savings in costs to tax payers by adding an extra unit of service capacity) provided. In this work, we determine the optimal number, locations and capacities of a network of facilities so as to maximize the overall benefit to the public.

**2 - Uniform Price Approximation in Elastic Demand Location Models**

Dmitry Krass, University of Toronto, Rotman School of Management, 105 St George Street, Toronto, ON, M5S 3E6, Canada, Oded Berman

We consider a location model with stochastic customer demand where demand rate is affected by service quality (waiting) and price. We show that under certain assumptions, the optimal pricing policy is uniform, with identical price charged at every facility. We then apply this policy as a heuristic for the general case, deriving both theoretical and computational performance bounds.

**3 - Locating Time-knapsacks for Optimising Operational Performance**

Mozart Batista de Castro Menezes, Kedge Business School - Bordeaux, Office: 1449, Talence, 33405, France, Diego Ruiz-Hernandez

In this work we analyse the way a manufacturer's fixed-costs should be allocated to each production order rather than the way they are currently allocated. Using that information, we introduce a facility location model where fixed-costs are incurred when opening a facility; time-knapsacks representing production lines are assigned to the facility, adding another layer of fixed-costs; and finally, production orders are allocated to knapsacks with corresponding variable costs. Using a real situation, resulting solutions have higher capacity utilisation, smaller and fewer facilities than current network design. Serving demand from closest facility is also less frequent.

**4 - Multi-period Home Healthcare Provider Facility Location-allocation Problem**

Vahid Roshanaei, University of Toronto, 1706 35 Charles Street West, Toronto, ON, M4Y 1R6, Canada, Oded Berman, Opher Baron

We study the facility location-allocation problem of a multi-period home healthcare provider in Toronto, Canada. We develop a mixed-integer programming model that considers (i) nurses' flexibility where nurses of higher skills can perform the tasks of nurses with lower skills, (ii) patients' continuity of care, and (iii) inter-facility resource-sharing. We demonstrate how inclusion of the above impact cost-savings.

**Sunday, 3:10PM - 4:00PM****■ Plenary**

West Bldg 301AB

**Plenary: Networks to Save the World: OR in Action**

Plenary Session

Chair: Timothy R. Anderson, Portland State University, Mail Code ETM, P.O. Box 751, Portland, OR, 97201, United States

**1 - Networks to Save the World: OR in Action**

Anna B. Nagurny, University of Massachusetts-Amherst, Isenberg School of Management, Dept of Operations & Information Mgmt, Amherst, MA, 01003, United States

Networks have evolved to become the foundational framework for a wide range of applications, beginning with classical transportation and logistics problems. In this talk, I will feature network-based results in multiple areas such as: perishable product supply chains from food to healthcare, disaster relief, cybersecurity, and the new Internet, and illustrate how netwORks are transforming our understanding of the world and enhancing our futures.

**Sunday, 4:30PM - 6:00PM****■ SD01**

North Bldg 121A

**Joint Session OPT/Practice Curated: Applications of Stochastic Programming**

Sponsored: Optimization/Optimization Under Uncertainty

Sponsored Session

Chair: Amanda G. Smith, University of Wisconsin-Madison, Madison, WI, 53706, United States

**1 - Leveraging Decomposition Methods to Design Robust Policies for Markov Decision Processes**

Lauren N. Steimle, University of Michigan, 3261 Bolgos Circle, Ann Arbor, MI, 48105, United States, Brian T. Denton

Markov decision processes (MDPs) are commonly used to derive optimal sequential decision-making policies. However, these policies can underperform if the true model parameters differ from the estimates used in the optimization process. To address this issue, the Multi-model MDP has been proposed as a way to find a policy that performs well with respect to multiple models of the MDP parameters. Finding a policy that maximizes a weighted value across the models can be viewed as a two-stage stochastic program, and leveraging this connection, we develop exact and approximate solution methods that can be used to generate MDP policies that are robust to deviations in model parameters.

**2 - Designing Resilient Distribution Systems Under Natural Disasters**

Sadra Babaei, Oklahoma State University, 322 Engineering North, Industrial Engineering & Mgmt, Stillwater, OK, 74078, United States

This talk proposes a distributionally robust model for designing a distribution power system to withstand the risk of disruptions imposed by natural disasters. Using the moment information of asset failures, we build an ambiguity set of probability distributions of system contingencies. On the one hand, we consider the stochasticity of natural disasters and provide a less conservative configuration than that by a robust optimization approach. On the other hand, our model considers distributional ambiguity and so is more reliable than stochastic programming. We recast the model as a two-stage robust optimization formulation and solve it using the Column-and-Constraint Generation framework.

**3 - Optimizing Flux Bound Change Decisions In Metabolic Engineering**

Amanda Smith, University of Wisconsin-Madison, Fitchburg, WI, 53711, United States, James Luedtke

Bilevel mixed-integer programming models are frequently used to solve metabolic engineering problems. However, these models tend to push cells close to infeasibility, and solutions may yield non-viable organisms. To overcome this drawback, we investigate three new bilevel MIP models that attempt to offer a compromise between desired output and organism viability. First, we introduce a bi-objective top-level problem. We then augment this model by incorporating enzyme kinetics and conclude with a stochastic extension that accounts for uncertainty in cellular behavior.

**4 - Distributionally Robust Dual Dynamic Programming**

Daniel Duque, Northwestern University, 2145 Sheridan Rd, Evanston, IL, 60208, United States, David Morton

We consider a multi-stage stochastic linear program that lends itself to solution by stochastic dual dynamic programming (SDDP). In this context, we consider a distributionally robust variant of the model with a finite number of realizations in each stage, and distributional robustness is with respect to the probability mass function governing candidate realizations. We describe a computationally tractable variant of SDDP to handle this model using the Wasserstein distance to characterize distributional uncertainty.

**■ SD02**

North Bldg 121B

**Optimizing Policies in Systems Under Uncertainty**

Sponsored: Optimization/Optimization Under Uncertainty

Sponsored Session

Chair: Omid Nohadani, Northwestern University, Evanston, IL, 60208-3119, United States

**1 - Performance Bounds for Multistage Distributionally Robust Optimization**

Eojin Han, Northwestern University, 2145 Sheridan Road, Tech C210, Evanston, IL, 60208, United States, Chaithanya Bandi, Omid Nohadani

Distributionally robust optimization for multistage problems are known to be computationally challenging. Several approximative policies have been proposed, however, without bounds on their performance. For these problems, we study finitely adaptable policies and provide performance guarantees along with tractable implementation. The proposed bounds are established only based on the geometry of the underlying ambiguity set. Therefore, these bounds are general and independent of other problem parameters. We examine their performance on a newsvendor problem, allowing further insights.

**2 - Sustainable Inventory with Robust Periodic-affine Policies and Application to Medical Supply Chains**

Omid Nohadani, Northwestern University, 2145 Sheridan Road, Technological Institute M233, Evanston, IL, 60208-3119, United States, Eojin Han, Chaithanya Bandi

We introduce a new class of adaptive policies called periodic-affine policies, that allow to optimally manage large-scale newsvendor networks under demand uncertainty. These policies are data-driven and can model, e.g., correlation. We then generalize the model to multi-product settings and multi-period problems. We show that these policies are sustainable, i.e. time consistent. This approach is tractable and free of distributional assumptions, hence, suited for real-world applications. We provide efficient algorithms and demonstrate them on one of India's largest pharmacy retailers.

**3 - Distributionally Robust Newsvendor with Variation Distance: Calibration under Limited Information and Application to Reserving Operating Room Time**

Hamed Rahimian, Northwestern University, 1971 Neil Avenue, 210 Baker Systems Building, Evanston, IL, 60208, United States, Guzin Bayraksan, Tito Homem-de-Mello

We use distributionally robust stochastic optimization to model a general class of newsvendor problems. We form the ambiguity set by all demand distributions whose total variation distances from a nominal distribution are bounded by a level of robustness. For this problem, we characterize the optimal solution and the regions of demand that are critical to the optimal cost. We also establish quantitative relationships between the distributionally robust model and the corresponding risk-neutral and classical robust optimization models. We use our analyses to recommend an appropriate level of robustness for an operating room time reservation problem.

**4 - Data-Driven Distributionally Robust Stochastic Programming for Correlated Data**

Mihai Anitescu, Argonne National Laboratory, Argonne, IL, United States, Xialiang Dou

We present a distributionally robust formulation of a stochastic optimization problem for non-i.i.d vector autoregressive data. We use the Wasserstein distance to define robustness in the space of distributions and we show, using duality theory, that the problem is equivalent to a tractable, finite concave-convex saddle point problem. The performance of the method is demonstrated on both synthetic and real data

## ■ SD03

North Bldg 121C

### Incentive Conflicts in New Product Development: Theory and Data

Sponsored: Technology, Innovation Management & Entrepreneurship

Sponsored Session

Chair: Jochen Schlapp, University of Mannheim, Mannheim, 68163, Germany

#### 1 - Turning the Tables: Licensing Contracts with Reciprocal Options

Pascale Crama, Singapore Management University, 50 Stamford Road, Singapore, 178899, Singapore, Niyazi Taneri

R&D collaborations between an innovator and a partner are often undertaken when neither can bring the product to market individually making joint effort necessary. Either party can avoid moral hazard by acquiring their missing capability and taking sole ownership of the project. The extent of two risks about whether the other party's capability will be acquired and about how well it will be implemented determine the optimality of not signing an up-front contract, signing buyout contracts, buyback contracts, dual buyout-buyback contracts, and an underutilized novel reciprocal option contract.

#### 2 - Project Selection and Success in Pharmaceutical R&D

Panos Markou, Cambridge Judge Business School, Calle Maria de Molina 12, Bajo, Cambridge, United Kingdom, Nektarios Oraopoulos, Stylianos Kavadias

We analyze the R&D pipelines of the fifteen largest pharmaceutical companies and examine how firms select which projects to pursue, and which ones eventually succeed, i.e., receive FDA approval. We find that firms select projects where they have prior experience, but that selection also depends on technological signals from rivals. Additionally, we find that in-licensed projects are less likely to be selected for development than in-house projects; but, conditional on selection, they have higher likelihood of success.

#### 3 - The Role of Participation in Innovation Contests

Jeremy Hutchison-Krupat, University of Cambridge, Cambridge, 22901, United Kingdom, Konstantinos Stouras, Raul Chao

We study a firm that chooses to employ an innovation contest only when the contest is expected to generate more value than alternative options. The population of solvers differ in their ability to generate value and they incur an opportunity cost to participate. Thus, some solvers may not find it beneficial to participate. Critically, when the firm designs the contest, and when the solvers choose to enter, the number of participants remains uncertain. Within this setting, we find that firms with sufficiently high opportunity cost maximize expected profit through the provision of multiple awards; otherwise, firms maximize their profit through a winner-take-all award structure.

#### 4 - Search Under Constraints

Sezer Ulku, Georgetown University, 594 Rafik B. Hariri Building, Washington, DC, 20057, United States

In innovation contexts, slack resources are required to allow experimentation in the face of uncertainty. At the same time, it is also suggested that "necessity is the mother of invention", and that constraints result in superior innovation performance. We conduct several experiments to investigate how constraints influence search behavior and the performance achieved in problem solving tasks. We find that solution quality attained under a moderate constraint is superior to that attained when no such constraint is present. As expected, when the resource constraint becomes very tight, performance suffers.

## ■ SD04

North Bldg 122A

### Joint Session: Integer Programming/Opt under Uncertainty: Stochastic Mixed-Integer Programming

Sponsored: Optimization/Integer and Discrete Optimization

Sponsored Session

Chair: Amy Burton, Clemson University, Clemson, SC, United States

#### 1 - An Affine Bounding Method for Two-stage Stochastic Integer Programs

Gustavo Angulo, Macul, Santiago, 7820436, Chile, Merve Bodur, Diego A. Moran

For two-stage stochastic programs with mixed-integer recourse, we propose a decomposition method akin to Benders' decomposition. To approximate the second-stage value function, we iteratively partition the first-stage feasible set with affine lower-bounding functions derived from a Lagrangian relaxation, which is shown to be exact at the vertices of each element of the partition. Preliminary computational results are also presented.

#### 2 - Mixed-integer Nonlinear Programming Method for Chance-constrained Models with Endogenous and Exogenous Uncertainty

Alan Delgado de Oliveira, The George Washington University, Washington, DC, United States, Miguel Lejeune, Francois Margot

We propose a chance-constrained stochastic programming model with endogenous and exogenous uncertainty and develop an MILP solution method. This study is motivated by the need to quickly evacuate severe casualties from the battlefield. Computational results will be presented.

#### 3 - On Distributionally Robust Chance Constrained Program with Wasserstein Distance

Weijun Xie, Virginia Tech, Blacksburg, VA, 24060, United States

In a distributionally robust chance constrained optimization problem (DRCCP), the chance constraint is required to hold for all probability distributions of the uncertain parameters within a chosen Wasserstein distance from an empirical distribution. In this work, we investigate equivalent reformulations and approximations of such problems. We first show that a DRCCP can be reformulated as a conditional-value-at-risk constrained optimization problem, and thus admits tight inner and outer approximations. Next, we show that a DRCCP is mixed integer representable. We further identify submodular substructure in DRCCP and hence are able to derive valid inequalities.

#### 4 - Applying Stochastic Mixed-integer Programming to the Resiliency of Transportation Networks

Amy Burton, PhD Student, Clemson University, Clemson, SC, United States, Akshay Gupta

The decisions that dictate how funds are used to protect and increase the resilience of transportation networks should be made in a methodical, studied, and well-attested way. Focusing on bridges as critical links in transportation networks, we propose a stochastic mixed-integer program to minimize: (1) the investment costs of repairing and improving bridges and (2) time and travel costs incurred by motorists when old and damaged structures fail. Bender's Decomposition is used to solve a convex formulation of the nonconvex mixed-integer nonlinear program. Computational results are presented for an example nine-node network as well as the benchmark Sioux Falls network.

## ■ SD05

North Bldg 122B

### First Order Methods for Nonlinear Optimization

Sponsored: Optimization/Linear and Conic Optimization

Sponsored Session

Chair: Negar Soheili Azad, University of Illinois-Chicago, Chicago, IL, 60607, United States

#### 1 - In-face Frank-wolfe for Non-convex Optimization

Paul Grigas, UC Berkeley, 4177 Etcheverry Hall, University of California, Berkeley, CA, 94720-1777, United States, Nathan Vermeersch

The Frank-Wolfe method and its extensions are well-suited for delivering solutions with desirable structural properties, such as sparsity or low-rank structure. We adapt the methodology of in-face directions within the Frank-Wolfe method to the setting of non-convex optimization. We are particularly motivated by the application of this methodology to the training of neural networks with sparse and/or low-rank properties. We develop theoretical computational guarantees, and we complement these results with extensive numerical experiments.

#### 2 - New Advances in Block Coordinate Descent Methods with Convergence to Second Order Stationary Solutions

Songtao Lu, University of Minnesota Twin Cities, Room 4-174 200 Union St SE, Minneapolis, MN, United States

The alternating gradient descent (AGD) is a simple but popular algorithm which has been applied to problems in optimization, machine learning, etc. In this talk, we show that a variant of AGD-type algorithms will not be trapped by "bad" stationary solutions such as local maximum points. In particular, we consider a smooth unconstrained optimization problem, and propose a perturbed AGD (PA-GD) which converges (with high probability) to the set of second-order stationary solutions (SS2) with a global sublinear rate. To the best of our knowledge, this is the first alternating type algorithm which takes  $O(\text{polylog}(d)/\epsilon^{7/3})$  iterations to achieve SS2 with high probability.



### 3 - First-order Methods for Non-convex Non-smooth minimax optimization

Qihang Lin, The University of Iowa, 21 East Market Street, S380, Pappajohn Business Building, Iowa City, IA, 52245, United States

In this paper, we consider the minimization of the maximum of finitely many weakly convex functions. Such a formulation has applications in machine learning and robust optimization. We model this problem equivalently as a min-max saddle-point problem. Due to the non-convexity, it is challenging to find a global saddle-point in general. We propose a primal-dual first-order method for this saddle-point problem and analyze the total iteration complexity of our method for finding an epsilon-nearly stationary point. Our method is developed for both stochastic and finite-sum problems.

### 4 - A Level Set Method for Constrained Stochastic Optimization

Negar Soheili, University of Illinois-Chicago, 601 S. Morgan Street, University Hall 2416, Chicago, IL, 60607, United States,  
Qihang Lin, Selvaprabu Nadarajah

Stochastic optimization problems with expectation constraints (SOEC) arise in several operations research and financial engineering applications. Only recently has an efficient stochastic subgradient method been developed for solving a SOEC defined by an objective and a single inequality constraint, where both are defined by expectations of stochastic convex functions. We develop a level-set method to compute near-optimal solutions to a generalization of this SOEC containing multiple inequality constraints, each involving an expectation of a stochastic convex function. We establish convergence guarantees for this method under different convexity assumptions.

## ■ SD06

North Bldg 122C

### Computational Stochastic Programming

Sponsored: Optimization/Computational Optimization and Software  
Sponsored Session

Chair: Rohit Kannan, PhD, University of Wisconsin, Madison, WI, United States

#### 1 - Recent Computational Advances in Multistage Stochastic Programs

Yongjia Song, Clemson University, 211 Fernow Street, 264 Freeman Hall, Clemson, SC, 29634, United States,  
Wim van Ackooij, Welington de Oliveira, Murwan Siddig

We consider decomposition techniques for multistage stochastic programming. The proposed algorithms combine ideas from finite perturbation of convex programs and level bundle methods to regularize the so-called forward step of these decomposition methods. On the other hand, the backward step of the decomposition methods is accelerated via recent developments in cutting plane approaches. Numerical experiments on a hydrothermal scheduling problem indicate that our algorithms are competitive with the state-of-the-art, e.g., the multistage regularized decomposition and the stochastic dual dynamic programming methods in the literature.

#### 2 - An Improved Branching Approach for Branch-and-bound Applied to Stochastic Mixed-integer Programs

Brian Christopher Dandurand, Argonne National Laboratory,  
Kibaek Kim

We present a new branch-and-bound approach for the extended split-variable form of stochastic mixed-integer programs. During the bounding of each node, we assume the generation of: 1) a set of "column" solutions satisfying integrality; and 2) a "consensus" solution satisfying non-anticipativity. Branching is informed by an interweaving of 1) the violations of consensus integrality, and 2) a suitable measure of dispersions of the column solutions around the consensus solution. The measure of dispersion adapts to the changing profile of integrality violation, and the branching scheme only requires branching on first-stage variables. We discuss computational tests on SIPLIB test problems.

#### 3 - A Scalable Global Optimization Algorithm for Stochastic Nonlinear Programs

Yankai Cao, University of Wisconsin-Madison, 2009 Engineering Hall, 1415 Engineering Drive, Madison, WI, United States,  
Victor Zavala

We present a reduced-space spatial branch and bound (BB) strategy for two-stage stochastic nonlinear programs. At each node, a lower bound is constructed by relaxing the non-anticipativity constraints and an upper bound is constructed by fixing the first-stage variables. Both lower and upper bounds can be computed by solving individual scenario subproblems. Another key property is that we only need to perform branching on the first-stage variables to guarantee convergence. We present an implementation of the algorithm called SNGO. We perform numerical experiments and compare the computational results against SCIP and demonstrate that the proposed approach achieves significant speedups.

#### 4 - GOSSIP: Decomposition Software for the Global Optimization of Nonconvex Two-Stage Stochastic Mixed-Integer Nonlinear Programs

Rohit Kannan, University of Wisconsin-Madison, Paul I. Barton

Despite rapid advances in decomposition techniques for solving two-stage stochastic MINLPs, there is, to the best of our knowledge, no publicly available software framework that implements these techniques. Motivated by the increasing interest in solving this rich class of problems, we present our decomposition framework named GOSSIP. GOSSIP includes implementations of nonconvex generalized Benders decomposition, Lagrangian relaxation, and a modified Lagrangian relaxation algorithm along with subroutines for detecting special structure and bounds tightening. The capabilities of GOSSIP are demonstrated on a library of diverse test instances composed from the literature.

## ■ SD07

North Bldg 123

### Joint Session OPT/Practice Curated: Network Analytics: Models and Applications

Sponsored: Optimization/Network Optimization

Sponsored Session

Chair: Jose Luis Walteros, University at Buffalo, SUNY, Buffalo, NY, 14260, United States

#### 1 - An Integer Programming Approach for Vertex Connectivity Interdiction Problems

Demetrios Papazaharias, University at Buffalo, Buffalo, NY, 14260, United States, Jose Luis Walteros

The vertex connectivity interdiction problem entails finding the minimum subset of vertices in an undirected graph whose deletion achieves a desired reduction in the graph's connectivity. In particular, we aim to reduce the size of the largest component to at most  $k$ . In this paper, we introduce a 0-1 linear programming model with an extended formulation and cutting planes to strengthen its LP relaxation. We present computational experiments to compare our results to competing formulations as well as highlight interesting results for graphs containing a special structure.

#### 2 - Distance Between Two Random Events in a Network

Ningji Wei, University at Buffalo, SUNY, Buffalo, NY, United States,  
Jose Luis Walteros, Rajan Batta

We are interested in the shortest distance  $D$  of two random events in any given connected network where the lengths of edges are not negligible. We found the closed form formula for its expectation, and any order higher moments. Also found its PDF in closed form. In application, we may encounter the situation that one distribution is under our control, so we also found those statistics for the shortest distance conditioning on one of the events. Further, we analyzed the property of these statistics, and also their computational complexity with respect to the size of the network. Finally, we applied our results on some special type networks.

#### 3 - Optimal Corridor Design in Fragmented Landscapes

Chao Wang, Arizona State University, Tempe, AZ, United States,  
Jorge A. Sefair

Corridor design is fundamental in conservation planning to mitigate the adverse effects of habitat fragmentation. Current approaches focus on network analysis and landscape features but ignore the likelihood of movement and species mortality. To overcome these challenges, we present a discrete time Markov chain approach that allows us to predict transient and long-term connectivity measures. We also discuss a MIP formulation to find corridors with the highest expected usage to connect a network of fragmented landscapes. We discuss our models using a real case study of human-wildlife conflict.

#### 4 - Studying the Trade-off Between Police Presence and Patrolling in a Road Network

Fatemeh Mousapour, University at Buffalo, Buffalo, NY, 14260, United States, Jose Luis Walteros, Rajan Batta

Patrolling and adequate coverage are two key factors in police patrol problems respectively to stop, deter and prevent crimes. Our approach integrates some aspects of the traditional orienteering problem within a patrolling model to examine the trade-off between police presence in specific spots and patrolling through a road network.

## ■ SD08

North Bldg 124A

**Joint Session OPT/Practice Curated: Network Design Models and Applications**

Sponsored: Optimization/Network Optimization

Sponsored Session

Chair: Navid Matin Moghaddam, Arizona State University, AZ

**1 - Large-scale Network Design with Application to Carbon Capture and Storage**Navid Matin Moghaddam, Tempe, AZ, 85281, United States,  
Jorge A. Sefair

Motivated by the emerging need of climate stabilization, CCS seeks to prevent carbon emissions from entering the atmosphere by capturing, compressing, and transporting CO<sub>2</sub> from sources (e.g., oil refineries) to geologic reservoirs (e.g., depleted oil wells) for its long-term storage. To find the least-cost network of pipelines able to transport a target amount of CO<sub>2</sub>, we propose an optimization model and an exact decomposition algorithm that takes advantage of the optimal solution sparsity and the problem's cost structure. We illustrate the performance of our methods on a set of real instances.

**2 - Profit Oriented Fixed-charge Network Design with Elastic Demand**Carlos Armando Zetina, Concordia University, 1455 de  
Maisonneuve Boulevard West, Montreal, QC, H3G 1M8, Canada,  
Ivan Contreras, Jean-Francois Cordeau

Networks require significant investments and their infrastructure is built to last over an extended period of time. It is unrealistic to believe that the demand patterns will remain the same during its lifetime. Moreover, demand patterns depend on the resulting network's topology, leading to sub-optimal designs if static estimations are used. We attempt to circumvent this by incorporating elastic demand into a fundamental network design problem. We replace static origin-destination demand estimations with functions of the network characteristics often used to estimate demand. This provides the decision-maker with insights on the effect the design has on demand patterns.

**3 - Using Network Optimization to Extend the Transit Opportunity Index for Large-scale Transit Systems**Andres L. Medaglia, Professor, Universiad de los Andes, Cr 1 este  
Bogota, 111711, Colombia, Claudia D. Bedoya, Olga L. Sarmiento,  
Daniel A. Rodriguez, Jessica Camacho

The Transit Opportunity Index (TOI) quantifies accessibility and connectivity of a public mass transit system by combining spatial, temporal, and trip coverage metrics. We extended the TOI to allow for connectivity in large-scale transit systems where more than one transfer may be required. In this extended TOI we build a time-space network from the public transit supply and find shortest paths allowing multiple transfers. With the extended TOI, transit planners could adjust transit service to include opportunities and accessibility as design goals and address equity by identifying underserved areas. We illustrate the extended TOI with the public transit network of Bogotá, Colombia.

**4 - The Wireless Network Design Problem Subject to Radio Interference**Hugh Medal, Mississippi State University, P.O. Box 9542, Msu, MS,  
39762, United States, Will Leonard, Randy K. Buchanan

This paper studies the wireless network design problem, which considers how best to place a set of antennas so that the antennas can send and receive data in a way that maximizes total network throughput. A mixed-integer program was implemented to solve this problem using a Benders-decomposition approach. Maximal independent sets representing antennas' connections to one another were produced dynamically. The goal of this paper is to demonstrate whether utilizing directional antennas instead of omnidirectional antennas affects maximum throughput, as well as what changes occur to maximum throughput based on imposing constraints related to power and channel availability.

## ■ SD09

North Bldg 124B

**Intersection between Optimization and Statistical Learning**

Sponsored: Optimization/Nonlinear Programming

Sponsored Session

Chair: Hongcheng Liu, University of Florida, Gainesville, FL,

**1 - Global Optimization of High-dimensional Generalized Linear Models with Nonconvex Regularization in Polynomial-time with High Probability**Charles Hernandez, University of Florida, Gainesville, FL, 32606,  
United States

In this presentation we investigate a local optimization scheme for a class of nonconvex learning problems known to be NP-Hard to solve. This optimization scheme can be shown to find a global optimum in polynomial time with high probability. The approach uses LLA in combination with a Folded Concave Penalty function and can be applied to the training of many high-dimensional generalized linear models.

**2 - Second-order Condition in Nonsmooth High-dimensional Learning**Hongcheng Liu, University of Florida, Weil Hall 478, Gainesville,  
FL, 32611, United States

This research concerns the high-dimensional learning with non-smooth empirical loss functions. Through the use of a folded concave penalty (FCP), we show that the excess risk of the M-estimation problem can be well contained even if the loss function is not necessarily differentiable and the number of dimensions cannot be bounded by any polynomial function of the sample size. Such a desirable sample complexity is provably achieved at a second-order stationary point of the FCP-based nonconvex formulation.

**3 - Linearly-constrained High Dimensional Learning**Hung Yi Lee, University of Florida, 303 Weil Hall, Gainesville, FL,  
32603, United States

This presentation is mainly concerned with the computational and statistical complexities involved in the folded concave penalized high-dimensional M-estimation problems with linear constraints. We have shown that by using some local solutions which satisfy certain second-order necessary optimality conditions, the required sample size grows in poly-logarithmic of the number of dimensions, hence, improving the statistical performance.

**4 - Complexity for Training ReLU Neural Network**Digvijay Boob, Georgia Institute of Technology, Atlanta, GA,  
United States, Santanu Subhas Dey, Guanghui Lan

A neural network is a function computed on a graph parameterized by edge weights. Problem of training neural network can be thought of as searching for edge weights such that output of neural network exactly matches with output according to data. It is known that training binary neural network is NP-complete whereas ReLU neural network is employed extensively in practice. Training algorithm involves heuristic methods such as stochastic gradient descent. There is a no complexity based hardness results for fully connected ReLU network. We show that training a simple fully connected ReLU neural network is NP-hard. On the other hand, applying over-parametrization to these networks render the problem in P.

## ■ SD10

North Bldg 125A

**Resource-Constrained Scheduling in Production and Project Management**

Sponsored: Manufacturing &amp; Service Oper Mgmt

Sponsored Session

Chair: Norbert Trautmann, University of Bern, FM Quantitative  
Methoden, Schuetzenmattstrasse 14, Bern, 3012, Switzerland**1 - The RCPSP: New Benchmark Results**Stefan Creemers, KU Leuven, Naamsestraat 69, Leuven, 3000,  
Belgium, Stefan Creemers, IESEG School of Management, Lille,  
France

We present a new state-of-the-art procedure for solving the resource-constrained project scheduling problem. We present new benchmark results, and are able to solve several problem instances that were previously unsolved.

## 2 - Mixed Integer Linear Programming Formulations for Resource Constrained Truck Scheduling in Cross Docks

Pascal Wolff, Tongji University, Shanghai, China, Yongrui Duan, Hans-Christian Pfohl, Jiazhen Huo

The number of articles on truck scheduling in cross-docks has been growing very fast in the last decades. However, many models are detached from industry practice since they do not explicitly consider resource constraints (e.g. available manpower, material handling equipment etc.). In this paper, we address this research gap and propose MILP formulations for truck scheduling in cross-docks that incorporate resource availability. Considering scarce resources that are required for cross-dock operations, these scheduling models meet industrial needs. Furthermore, we develop heuristic algorithms to tackle the problems.

## 3 - Capacity Planning and Production Scheduling for a Multi-facility Production System

Nourah Almatooq, Arizona State University, Tempe, AZ, United States, Ronald G. Askin, Greg Gruber

We investigate the integrated medium-range capacity planning and production scheduling problem for a multi-facility system producing multiple products with significant capacity change, semi-fixed and variable labor, shortage and logistics costs. We find the optimal production quantities, shift schedules, processing rates, overtime, inventory policy and shipments to demand markets to minimize system costs over the multiperiod planning horizon. Strategies for capacity modification to match dynamic demand are determined.

## 4 - A Novel Continuous-time Model for the Resource-constrained Project Scheduling Problem RCPSP

Norbert Trautmann, University of Bern, FM Quantitative Methoden, Schuetzenmattstrasse 14, Bern, 3012, Switzerland, Adrian Zimmermann

The widely studied resource-constrained project-scheduling problem RCPSP consists of determining the start times for a set of precedence-related project activities requiring time and scarce resources during execution such that the total project duration is minimized. We present a novel continuous-time MILP model which outperforms various state-of-the-art models in particular when the resource capacities are very scarce.

## SD11

North Bldg 125B

## Socially Responsible and Demand-driven Operations Management

Sponsored: Manufacturing & Service Oper Mgmt

Sponsored Session

Chair: Muge Yayla Kullu, University of Central Florida, Orlando, FL, 32816, United States

### 1 - Nowcasting Restaurant Hygiene using Online Reviews

Shawn Mankad, Cornell University

We provide evidence for how information from online reviews of restaurants can be effectively used to identify cases of hygiene violations in restaurants, even after the restaurant has been inspected and certified. We use data from restaurant hygiene inspections in New York City from the launch of an inspection program from 2010 to 2016, and combine this data with online reviews for the same set of restaurants. Using machine learning techniques, we identify systematic instances of moral hazard, wherein restaurants with positive hygiene inspection scores are seen to regress in their hygiene maintenance within 90 days of receiving the inspection scores.

### 2 - Product Design and Pricing in Integrated Repair Supply Chain

Honggang Hu, University of Florida, Gainesville, FL, 32611, United States, Avinash Geda, Vashkar Ghosh, Asoo J. Vakharia

Firms are producing highly integrated products which are less repairable by third party repair firms. While firms lose out on consumers who value repairable products, they offer the firms a source of repair service revenue downstream. We address the issue where the firms faces trade-off between product design and potential revenue from repair services.

### 3 - Sustainable Management with a Triangle Sustainable Framework: Cases of Sustainable Manufacturing

Yong Yin, Doshisha University, Karasuma-Imadegawa, Kamigyo-ku., Kyoto, 602-8580, Japan, Kathryn E. Steckle, Dongni Li

Triple bottom line is extended to a triangle sustainable framework that consists of categories of primary performance measures and drivers that address the relationships among the economic, environmental, and societal sustainable dimensions. Manufacturing cases of seru production are used to show that following particular practices and performance goals (e.g., pursuing responsiveness) naturally lead to sustainable outcomes. Our results are counter to the literature that claims that giving highest priority to the economic dimension makes it difficult to realize sustainability. A causal loop is used to identify sustainable drivers that induce a seru system to deliver sustainable goals.

## 4 - Recyclability of Post-disaster Debris

Andriy Shapoval, Georgia Institute of Technology, Atlanta, GA, United States, Pinar Keskinocak, Beril Toktay

This work investigates trade-offs in efforts to recycle debris after natural disasters. Various policies and interests of involved stakeholders may impact the possibility of creating efficient recycling programs. We evaluate the conditions under which recycling is viable across three dimensions: economic, environmental, and social.

## 5 - Reining in Onion Prices by Introducing a Vertically Differentiated Substitute

Muge Yayla Kullu, University of Central Florida, 4000 Central Florida Blvd., Orlando, FL, 32816, United States, Omkar D. Palsule-Desai, Srinagesh Gavirneni

Onion is an indispensable ingredient of the Indian diet and plays a vital role in the Indian economy, society, and politics. In this paper, we are interested in examining underlying causes of the onion price volatility that leads to significant social unrest in the country. We identify conditions under which (i) it is optimal to introduce the processed produce as a vertically differentiated substitute to the fresh produce; and (ii) the processed produce should be managed by cooperatives instead of private firms. Our model captures (i) competition between non-profit and for-profit organizations, (ii) consumers' valuation discount for processed produce, and (iii) perishability of the fresh produce.

## SD12

North Bldg 126A

## Using Estimated Data in Optimization

Emerging Topic: OR Frontiers

Emerging Topic Session

Chair: Meinolf Sellmann, Cortlandt Manor, NY, 10567, United States

### 1 - A Hybrid Decision Diagram and Mixed-integer Programming Approach for Optimization

Jaime E. Gonzalez, Polytechnique Montreal, Montreal, QC, Canada, Andre Augusto Cire, Andrea Lodi, Louis-Martin Rousseau

We present an optimization framework which integrates binary decision diagrams (BDDs) and mixed-integer programming (MIP) technology. In the proposed framework, a relaxed BDD plays the role of a search tree by identifying parts of the search space that can be efficiently explored by solving MIP models associated with the nodes of the BDD. Conversely, the MIP model results are iteratively employed to further refine the BDD and find primal bounds. Selecting the BDD nodes to explore by MIP highly impacts the approach's performance and then, the integration of supervised learning can be critical for this purpose. We present computational experiments on the maximum stable set problem.

### 2 - Maximizing the Expected Value of Order Statistics, with an Application to Sports Betting Pools

David Bergman, University of Connecticut, Storrs, CT, United States, Carlos H. Cardonha, Jason P. Imbrogno, Leonardo Lozano

Real-world optimization problem often require maximizing the expected value of order statistics. We discuss algorithms for solving this general and complex class of optimization problems, and describe how they can be applied to optimally selecting entries in sports betting pools.

### 3 - Predictive and Prescriptive Analytics for Location Selection of Add-on Retail Products

Teng Huang, University of Connecticut, Storrs, CT, 06268, United States, David Bergman, Ram Gopal

In this paper we study a predictive-and-prescriptive analytics framework for optimizing expansion decisions for retailers selling add-on products. We build predictive models for understanding the derived demand of the add-on product and establish an optimization framework for automating expansion decisions to maximize expected sales.



## ■ SD13

North Bldg 126B

**Navigating the Publication Process: Recently Published Papers in Empirical Healthcare OM**

Sponsored: Manufacturing &amp; Service Oper Mgmt/Healthcare Operations

Sponsored Session

Chair: Song-Hee Kim, University of Southern California, Los Angeles, CA, 90089, United States

**1 - When Waiting to See a Doctor is Less Irritating:****Understanding Patient Preferences and Choice Behavior in Appointment Scheduling**Nan Liu, Boston College, 140 Commonwealth Avenue,  
Fulton Hall, Room 340, Chestnut Hill, MA, 02467, United States,  
Stacey Finkelstein, Margaret Kruk, David Rosenthal

In this talk, we share the journey of our recent research and its publication process. This study concerns patient preferences and choice behavior in scheduling medical appointments. We conduct four discrete choice experiments on two distinct populations and identify several “operational attributes (e.g., delay to care and choice of doctor) that affect patient choice. We observe an interesting gender effect with respect to how patients tradeoff speed (delay to care) vs. quality (doctor of choice), and demonstrate that risk-attitude is a mediator variable. Our results have important implications for improving patient experience in a medical practice based on patient mix and current delay level.

**2 - Variety and Experience: Learning and Forgetting in the Use of Surgical Devices**Kamalini Ramdas, London Business School, A215 Sussex Place,  
Regent's Park, London, NW1 4SA, United Kingdom

We examine learning and forgetting in hip surgery as a function of surgeons' experience with specific device versions. We develop a generalizable method to correct for left censoring of granular experience data, using maximum simulated likelihood estimation. With steep learning and rapid forgetting, device variety hurts surgeons' productivity and quality.

**3 - Team Familiarity and Productivity in Cardiac Surgery Operations: The Effect of Dispersion, Bottlenecks, and Task Complexity**Bilal Gokpinar, UCL School of Management, 1 Canada Square  
(38th floor), Canary Wharf, London, E14 5AA, United Kingdom,  
Emmanouil Avgerinos

Fluid teams are commonly used by a variety of organizations to perform similar and repetitive yet highly critical and knowledge-intensive tasks. Using a granular data set of 6,206 cardiac surgeries from a private hospital in Europe over seven years, our study offers a new and detailed account of how shared work experience influences team productivity. We highlight the role of nuanced team composition dynamics beyond average team familiarity. We observe that teams with high dispersion of pairwise familiarity exhibit lower team productivity, and the existence of a “bottleneck-pair may significantly hinder overall knowledge transfer capability, thus, productivity of fluid teams.

**4 - The Impact of E-Visits on Visit Frequencies and Patient Health: Evidence from Primary Care**Hessam Bavafa, Assistant Professor, Wisconsin School of Business,  
975 University Avenue, Madison, WI, 53706, United States,  
Lorin Hitt, Christian Terwiesch

Secure messaging, or “e-visits,” between patients and providers has increased sharply in recent years, and many hope they will help improve healthcare quality while increasing provider capacity. Using a panel dataset from a large healthcare system in the United States, we find that e-visits trigger about 6% additional office visits, with mixed results on phone visits and patient health. These additional visits come at the sacrifice of new patients: physicians accept 15% fewer new patients each month following e-visit adoption. Our dataset on nearly 100,000 patients spans from 2008 to 2013, which includes the rollout and diffusion of e-visits in the health system we study.

## ■ SD14

North Bldg 126C

**Data and Platforms**

Sponsored: Manufacturing &amp; Service Oper Mgmt/Service Operations

Sponsored Session

Chair: Hamsa Sridhar Bastani, Wharton School, Philadelphia, PA, United States

Co-Chair: Kenneth Moon, University of Pennsylvania, Philadelphia, PA, 19104, United States

**1 - Network Effects in Contagion Processes Identification and Control**Fanyin Zheng, Columbia University, Columbia Business School,  
412 Uris Hall, New York, NY, 10027, United States,  
Kimon Drakopoulos

In this paper, we study the problem of identifying network effects in contagion processes and present an application to the propagation of influenza in the United States. In particular, using data on the evolution of infections over time, the travel intensity between states as well as environmental conditions we first provide a framework to identify the true network effect of traveling between states. We use our estimates to propose and evaluate the performance of intervention and control policies, illustrating the benefits of network-based interventions.

**2 - The Value of Pop-up Stores in Driving Online Engagement in Platform Retailing: Evidence from a Large-scale Field Experiment with Alibaba**Dennis Zhang, University City, MO, 63124, United States,  
Hengchen Dai, Lingxiu Dong

Short-lived and experiential-oriented pop-up stores have become a mainstream retail strategy. We provide the first causal evidence on how pop-up stores affect consumers' subsequent behaviors. In a randomized field experiment involving approximately 800,000 consumers with Alibaba Group's China's largest e-commerce company we randomly assigned consumers to either receive a message about an upcoming pop-up store event or not receive any message. Our results show that visiting a pop-up store not only increases customers' engagement with participating brands, but also improve customers' long-term engagement with the platform.

**3 - Optimal Recommendations and Preference Learning with Customer Disengagement**Divya Singhvi, MIT, Hamsa Sridhar Bastani, Pavithra Harsha,  
Georgia Perakis

We consider the problem of sequential product recommendations when customer preferences are unknown and customers are restless (i.e., customers decide to stay on the platform based on the quality of recommendations). In particular, we model customers who may abandon a content recommender (e.g., Pandora, Netflix) for an outside option (e.g., Apple Music or Hulu) based on the quality of recommendations they have received so far. We prove that bandit learning algorithms over-explore and the greedy policy under-explores in this regime. We propose a new learning algorithm that carefully balances the exploration-exploitation tradeoff in this setting.

**4 - Flexibility and Relationships in Online Marketplaces**Jiding Zhang, The Wharton School, 3730 Walnut St, 500 Jon M.  
Huntsman Hall, Philadelphia, PA, 19104, United States,  
Elena Belavina, Karan Girotra, Kenneth Moon

Online marketplaces have grown and diversified as intermediaries for services, extending from the flexible (Uber and Airbnb) to those in which trust and relationships are valued (\$800B home services market). Using data from a leading online labor marketplace, we empirically relate the operational performance of the platform's pricing and matching regimes to a simple market characteristic: how clients derive comparative value from flexibility and/or relationships with service providers. Extending recent theoretical modeling in dynamic mechanism design, our structural empirical methods use large-scale market data to prescribe pricing and matching policies.

**5 - Adaptive Learning with Unknown Information Flows**

Ahmadreza Momeni, Stanford University, Yonatan Gur

We introduce a generalized multi-armed bandit formulation in which additional information on each arm may appear arbitrarily throughout the decision horizon, and study the impact of such information flows on the achievable performance and the design of efficient decision-making policies. We characterize the regret complexity of this family of problems and introduce a general and practical adaptive exploration approach for designing policies that, without any prior knowledge on the information arrival process, attain the best performance that is achievable when the information arrival process is a priori known.

## ■ SD15

North Bldg 127A

**Joint Session MSOM/Practice Curated: Managing Customer in Service Systems: Emergency Department and Call Center Applications**

Sponsored: Manufacturing &amp; Service Oper Mgmt/Service Operations

Sponsored Session

Chair: Laurens G. Debo, Dartmouth College, Hanover, NH, 03755, United States

**1 - Modeling and Improving Emergency Department Operations**  
Tava Olsen, University of Auckland, ISOM, Business School,  
University of Auckland, Auckland, 1142, New Zealand

This talk presents a number of different streams of my research on modeling and improving ED operations. I consider issues of modeling patients leaving without being seen (with Bolandifar, DeHoratius, and Wiler), key drivers of ED performance (with Shaw, Parsons, and Walker), and issues in patient prioritization (with O'Sullivan, Walker, and Ziedins).

**2 - Dynamic Resource Allocation in an Emergency Department: A Tandem Queueing Model with Time-varying Arrivals**Ling Zhang, North Carolina State, Raleigh, NC, United States,  
Serhan Ziya, Sukriye Nilay Argon, Yunan Liu

Motivated by daily operations in an emergency department of a hospital, we study a multi-server tandem queueing system with a time-varying arrival rate. We are particularly interested in the optimal allocation of resources (such as nurses, doctors, and beds) among patients at different stages of service within a given cycle (e.g., a day). We solve an optimal control problem with an objective of minimizing the overall operational costs (including holding and staffing costs). Asymptotic analysis and numerical experiments are conducted to provide useful insights.

**3 - The Reference Effect of Delay Announcements: A Field Experiment Presenter**Qiuping Yu, Kelley School of Business, Indiana University, 1309 E.  
Tenth Street, Bloomington, IN, 47405-1701, United States,  
Gad Allon, Achal Bassamboo

We explore whether customers are loss averse in time and how delay information may impact such reference-dependent behavior via a field experiment at a call center. Customers are provided with delay announcements or no announcements in a quasi-randomized manner in our field experiment. We show that customers are loss averse regardless of the announcements. While delay announcements do not alter the nature that customers are loss averse, they do facilitate more granular learning of the offered waiting time and thus impact the reference point customers use. Through counterfactual studies, we demonstrate how customers' loss aversion behavior impacts the value of providing delay information.

**4 - Patients Waiting Experience in an Urban Emergency Department**  
Sina Ansari, Northwestern University, McCormick School of  
Engineering, 2145 Sheridan Road, Evanston, IL, 60208,  
United States, Laurens G. Debo, Seyed Iravani

Excessive wait time is the most common reason patients become unsatisfied and leave the emergency department before being treated. In this study, we determine the impact of announcing patient's waiting times on patients satisfaction.

## ■ SD16

North Bldg 127B

**Topics in Sustainable Operations**

Sponsored: Manufacturing &amp; Service Oper Mgmt/Sustainable Operations

Sponsored Session

Chair: Ximin Huang, University of Minnesota, Minneapolis, MN,  
55455, United States**1 - Network Architecture in Joint Liability Contracts**Bahar Rezaei, UCLA Anderson School of Management, CA,  
United States, Sriram Dasu, Reza Ahmadi

Joint liability contracts depend on the structure of the borrower network. We develop a model, in which connections between borrowers serve as monitoring tools, and examine the effect of various network structures on the performance of a jointly liable group. Our results show that a higher degree of connectivity has two counteracting effects on the group performance and consequently on the contract they are offered. Although, strong links between borrowers improve the group repayment insurance, it increases the repayment obligation of individual borrowers. We argue that for handling projects with average risk of failure, network structures with average connectedness are the best.

**2 - The Impact of Animal Welfare Regulation on Firms' Product Offerings: Humane or Organic Product**Wenli Xiao, University of San Diego, 5998 Alcala Park, Olin Hall  
335, San Diego, CA, 92110, United States, Yen-Ting Lin,  
Yinping Mu

We consider two competing supply chains with a supplier and a retailer. We examine the retailers' choice between offering an organic product and a humane product, when an animal welfare regulation is introduced. By offering an organic product, the retailer improves both animals' living conditions and the product's nutritional benefits, while offering a humane product only improves animals' living conditions. We provide the conditions under which the retailer would choose to offer the organic versus humane product. In addition, we show that subsidies offered by regulators to encourage the consumption of humane product in general hurts social welfare.

**3 - Impact of Carbon Pricing on Supply Chain Energy Efficiency and Social Welfare**Jason Quang Nguyen, University of New South Wales,  
Kensington, Sydney, 2052, Australia, Karen L. Donohue,  
Mili Mehrotra

This paper analyzes the trade-off between the intended benefit of carbon pricing in making emitters internalize the negative externality of emissions and its adverse effect on business competitiveness against external jurisdictions with a laxer policy. We study the policy decisions of a regulator who wishes to use carbon pricing to regulate emissions and encourage supply chain energy efficiency investments. Through a series of game theoretic models, we show that when it is important to maintain domestic business, social welfare could be reduced by the recommended practice of setting the carbon price equal to the negative externality from energy as well as by external jurisdiction competition.

**4 - Fair Labor Practices in a Sustainable Supply Chain: Buyers and Suppliers Managing Risk**Susan A. Slotnick, Cleveland State University, OSM Department,  
BU 542, Cleveland, OH, 44115, United States, Matthew J. Sobel

This paper investigates the collaborative decision making of a buyer and supplier, when the buyer's reputation in the market affects retail demand. Both buyer and supplier make decisions about managing the risk of an adverse event. The buyer maximizes profit by choosing among financial incentives to induce fair labor practices at the supplier, and the supplier manages its workforce and other resources to maximize its profit, considering the incentives and the risk.

## ■ SD17

North Bldg 127C

**Economic Models in Supply Chain Management**

Sponsored: Manufacturing &amp; Service Oper Mgmt/Supply Chain

Sponsored Session

Chair: Abhishek Roy, Temple University, Fox School of Business,  
Philadelphia, PA, United States

Co-Chair: Guoming Lai, Austin, TX, 78712, United States

**1 - Price Distributions, Store Sequencing, and Opportunistic Shopping Behavior**Sreekumar R. Bhaskaran, Southern Methodist University, Cox  
School of Business, P.O. Box 750333, Dallas, TX, 75275, United  
States, John H. Semple

This paper investigates the optimal sequence of store visits for items whose prices are unknown. We find that the shape of the price distribution plays an influential but sometimes non-intuitive role in lowering expected costs for the buyer.

**2 - Supplier Audit Information Sharing and Responsible Sourcing**Yunjie Wang, Renmin University of China, Beijing, China,  
Albert Y. Ha, Weixin Shang

We develop a game-theoretic model to study the incentive for competing manufacturers to share supplier audit information in a market with some consumers who boycott a manufacturer if supplier responsibility violations occur. Based on the audit information, each manufacturer either continues to source from an existing common supplier who has uncertain responsibility risk, or switches to a new supplier who has no responsibility risk but charges a higher price. We characterize the manufacturers' equilibrium audit information sharing decisions and sourcing strategies, and show how they depend on the model parameters.

**3 - Strategic Inventory under Supply Chain Competition**

Yanzhi David Li, City University of Hong Kong, Hong Kong, Li Xi, Ying-Ju Chen

We examine the effect of strategic inventory in the presence of chain-to-chain competition. We show that as the competition between two supply chains becomes fiercer, retailers will carry more inventory, which intensifies the supply chain competition. Consequently, this competition intensification effect can overshadow the effect of double marginalization alleviation.

**4 - Strategic Inventory in Non-exclusive Reselling Environments**

Abhishek Roy, Temple University, Fox School of Business, Philadelphia, PA, United States, Stephen M. Gilbert, Guoming Lai

Although the effects of strategic inventory in dynamic contracts on supply chain agents in bilateral monopolies are well known, we find that those effects are altered when competing manufacturers sell partially substitutable products through a common retailer. We examine the manufacturers' choices between a dynamic contract and a commitment contract that includes both price and quantity commitments. In contrast to what occurs in a bilateral monopoly, we find that manufacturers may prefer to use commitment contracts and that such contracts may arise in equilibrium.

**SD18**

North Bldg 128A

**Social Learning in Operations**

General Session

Chair: Gad Allon, The Wharton School of University of Pennsylvania, Philadelphia, Pennsylvania

**1 - Pricing and Prioritizing Differentiated Services when Customers Learn Socially**

Koushiki Sarkar, Kellogg School of Management, Northwestern University, Evanston, Saint Barth lemy, Gad Allon, Achal Bassamboo

Dissemination of information via social networks play a critical role in modern decision-making. We model the effects of social information in service differentiation under a queuing setting. We consider a profit-maximizing firm serving two groups of customers in an M/M/1 queue with two priority classes, where the customers observe service reviews at random from each period and use that information to decide their action for the coming period. We study the steady-state behavior of this system and obtain the firm's profit function and the optimal prices to be set.

**2 - Learning, Welfare, and Profits in Two-sided Service Platforms**

Kostas Bimpikis, Stanford University, Stanford, CA, United States, Yiangos Papanastasiou, Wenchang Zhang

Platforms such as Airbnb and Upwork have reduced search and information frictions in the service industry. The efficient gathering of information about the quality of providers in such a setting is of first-order importance. Our goal is to provide design guidelines taking into account that the quality of new providers is unknown and information about them can only be generated via transactions. The main design levers we explore are commission rates and information disclosure policy. We show that the optimal design features disclosing quality information with a delay and can result in significantly higher revenues than in the case that the platform does not optimize over information provision.

**3 - Which Locations are the Most Valuable in a Network of Service Outlets?**

Masha Shunko, University of Washington, Foster School of Business, PACCAR Hall, Seattle, WA, 98195, United States, Qiuping Yu, Shawn Mankad

Using a comprehensive dataset from a major restaurant network, we evaluate the impact of a restaurant's quality as measured by customer satisfaction and the impact of supply chain quality measured by quality complaints between supply chain members on the total sales at all locations within the network. As a result we identify the most valuable locations in terms of their impact on the total sales in the network, providing guidance on which service outlets should be prioritized for investment and development.

**4 - Value of Traceability in Supply Chains**

Yao Cui, Cornell University, Ithaca, NY, United States, Ming Hu, JingChen Liu

We consider supply chains where the buyer cannot identify which supplier is at fault when quality defect occurs (e.g., agricultural supply chains). We study how new technologies that enable traceability (e.g., blockchain) can create value under different supply chain structures.

**SD19**

North Bldg 128B

**Innovations in Pricing**

Sponsored: Revenue Management & Pricing

Sponsored Session

Chair: Adam Elmachet, Columbia University, New York, NY, 10027, United States

Co-Chair: Michael Hamilton, Columbia University, New York, NY

**1 - Network Revenue Management under Strategic Behavior and Customer Choice**

Nikolaos Trichakis, MIT, 100 Main Street, E62-576, Cambridge, MA, 02143, United States, Yiwei Chen

We consider a canonical network revenue management model in which a seller offers multiple products, which consume capacitated resources, for sale to utility-maximizing customers who choose both (1) when to buy, and (2) which product to buy. We use a novel decomposition approach for a suitable dynamic mechanism design problem to derive for all non-anticipating dynamic pricing policies an upper bound to expected revenues. We employ the bound to obtain a constant-factor guarantee for the performance of static pricing in a fluid-type regime.

**2 - The Impact of IPO on Peer-to-Peer Lending Platforms**

Kevin Jiao, NYU Stern, New York, NY, 10012, United States, Maxime Cohen

In this talk, we investigate the event of initial public offering and its impact on the peer-to-peer lending U.S. market. Focusing on the two leading U.S. platforms, we exploit a research setting which compares the difference between the private platform (Prosper) and the public platform (Lending Club) from both operational and investment perspectives. Using econometrics tools, we carefully examine if the event of IPO causes the firm to manipulate some of its operational decisions.

**3 - Price Optimization for Rotable Spare Parts**

Yunjie Sun, Columbia University, 500 West 120th Street, 535 S. W. Mudd Building, New York, NY, 10027, United States, Omar Besbes, Adam Elmachet

Working in collaboration with Dassault Falcon Jet (DFJ), we address the problem of pricing for rotatable parts, one special type of spare part that can be repaired and reused. We develop a model to maximize the expected profit rate through selling rotatable parts. This model captures the special dynamics of rotatable parts yet still easy to implement. We also discuss the on-going large scale implementation of the pricing model at DFJ. We leverage data in estimating the inputs for the optimization model. We build a user interface which takes the estimated inputs and returns a suggested price that is robust to uncertainties of inputs. We provide initial results of implementation for over 500 parts since May 2018.

**4 - The Power of Opaque Products in Pricing**

Michael Hamilton, Columbia University, New York, NY, 10027, United States, Adam Elmachet

We study the power of selling opaque products, i.e., products where a feature is hidden from the customer until after purchase. We consider models where traditional items are sold at a single price alongside opaque products corresponding to subsets of items and benchmark our opaque selling strategies against two common selling strategies: one which charges different prices for the items (discriminatory pricing), and one which charges a single price (single pricing). When customers are unit-demand and draw valuations exchangeably, we give a sharp characterization for when opaque selling outperforms discriminatory pricing, and characterize the maximal revenue lift opaque products can provide.



## ■ SD20

North Bldg 129A

### Revenue Management for Online Ad Markets

Sponsored: Revenue Management & Pricing

Sponsored Session

Chair: Negin Golrezaei, Massachusetts Institute of Technology, 30 Memorial Dr, Cambridge, MA, 02142, United States

Co-Chair: Antoine Desir, Google Inc, New York, NY, United States

#### 1 - Using Bundle Sales to Speculate on Price Elasticities for an Online Retailer

Will Ma, Massachusetts Institute of Technology, 71 School Street, Cambridge, MA, 02139, United States, David Simchi-Levi

This work is motivated by the observation that bundle sales numbers generally contain richer information about demand, and specifically, contain information about price elasticities that individual sales numbers do not. We propose a basic rule for using bundle sales to speculate on price elasticities. We test the validity of this simple rule on a data from a large online retailer and show that our speculations are correct with statistical significance.

#### 2 - Planning Online Advertising using Lorenz Curves

John G. Turner, University of California - Irvine, The Paul Merage School of Business, Room SB2 338, Irvine, CA, 92697-3125, United States, Miguel Lejeune

Lorenz curves are commonly-used to depict dispersion; e.g., income inequality. Motivated by online advertising campaigns that desire impressions spread over targeted audience segments and time, we formulate a problem that minimizes Gini Coefficients (area under the Lorenz curve), and develop a specialized decomposition technique to solve instances quickly.

#### 3 - Auction Design for ROI-constrained Buyers

Ilan Lobel, New York University, New York, NY, United States, Negin Golrezaei, Renato Paes Leme

We combine theory and empirics to (i) show that some buyers in online advertising markets are financially constrained and (ii) demonstrate how to design auctions that take consider such financial constraints. Using a field experiment on Google's advertising exchange, we find that a significant set of buyers lowers their bids when reserve prices go up. We show that this behavior can be explained if we assume buyers have constraints on their minimum return on investment (ROI). We proceed to design auctions for ROI-constrained buyers. We show that optimal auctions for symmetric ROI-constrained buyers are either second-price auctions with reduced reserve prices or subsidized second-price auctions.

## ■ SD21

North Bldg 129B

### Learning and Optimization in Revenue Management Problems

Sponsored: Revenue Management & Pricing

Sponsored Session

Chair: Huanan Zhang, Penn State University, 310 Leonhard Building, University Park, PA, 16801, United States

#### 1 - Nonparametric Learning with Covariates

Ningyuan Chen, Hong Kong University of Science and Technology, Clear Water Bay, Kowloon, Hong Kong, Guillermo Gallego

Decision makers usually need to optimize an initially unknown objective function with observed covariates. When the form of the objective function is unknown, postulating a parametric model of the function may lead to misspecification. We consider a nonparametric policy, which achieves a regret of order  $O((\log(T)^{2T}((2+d)/(4+d)))^{\frac{1}{2}})$ , where  $T$  is the length of the horizon and  $d$  is the dimension of the covariate. The algorithm is shown to be near-optimal. The role played by  $d$  highlights the complex interaction between the nonparametric formulation and the covariate dimension; It also suggests the decision maker incorporate contextual information selectively when possible.

#### 2 - Size Matters, so does Duration: The Interplay between Offer Size and Offer Deadline

Zhenyu Hu, National University of Singapore, 15 Kent Ridge Drive, Mochtar Riady Building, BIZ1 8-69, Singapore, 119245, Singapore, Wenjie Tang

We study a Stackelberg game involving a proposer and responder. The proposer acts first by making an offer to the responder with a deadline, and the responder, following a continuous finite-horizon search for alternative offers, has to respond to the offer by the deadline. We find that the proposer should offer a non-

exploding offer when the alternative offer market is favorable to the responder. When the alternative offer market is unfavorable to the responder, the proposer can profit from making an exploding offer with a smaller size in a harsher market. Finally, when the proposer is only allowed to manipulate offer size, the optimal offer size first decreases then increases in the given offer duration.

#### 3 - Dynamic Segmentation to Explore Markets with Unknown and Time-varying Customer Heterogeneity

N. Bora Keskin, Duke University, Fuqua School of Business, 100 Fuqua Drive, Durham, NC, 27708-0120, United States, Meng Li

Consumers are often heterogeneous in their preferences for product quality, and firms usually face uncertainty about consumer preferences when they sell vertically differentiated products to such heterogeneous consumers. We study this problem in a setting where a firm can dynamically optimize its prices. We construct and analyze near-optimal dynamic pricing policies in this context.

#### 4 - Online Learning and Optimization of (some) Cyclic Pricing Policies for Revenue Management with Patient Customers

Huanan Zhang, Penn State University, 903B West Aaron Dr., State College, PA, 16803, United States, Stefanus Jasin

We consider the joint learning and optimization problem of cyclic pricing policies in the presence of patient customers. We first introduce a learning algorithm that can converge to an optimal decreasing cyclic policy with a logarithmic regret, by only using the total sales information. Then, we introduce a larger family of policies, called threshold-regulated policies, which contains both the decreasing cyclic policies and the nested decreasing cyclic policies. For this broader set of policies, we introduce our second learning algorithm that can converge to an optimal threshold-regulated policy with logarithmic regret.

## ■ SD22

North Bldg 130

### Computational Methods

Sponsored: Revenue Management & Pricing

Sponsored Session

Chair: Dan Zhang

Co-Chair: Saied Samiedaluie, University of Alberta, Alberta School of Business, Edmonton, AB

#### 1 - Exact First-choice Product Line Optimization

Velibor Misis, UCLA Anderson School of Management, Los Angeles, CA, 90095, United States, Dimitris Bertsimas

The first-choice product line design problem is to select a set of candidate products to offer to a set of customers that choose according to a first-choice rule. We present a new MIO formulation of the problem, prove that this formulation is stronger than alternative models and develop a large-scale solution approach based on Benders decomposition. Using real data, we consider a product line problem involving over 3000 candidate products and over 300 respondents and show that our approach can solve this problem to provable optimality in 10 minutes (compared to 1 week in prior work).

#### 2 - Optimizing the Anheuser Busch Trailer Selection and Matching Problem

Jacob Feldman, Olin Business School, United States, Panos Kouvelis, Xingxing Chen, Seung-Hwan Jung

AB delivers its beer to vendors via third party trucks. For each third party truck that arrives to the warehouse, AB must match this truck with a preloaded trailer of beer. The gross weight of the trailer and truck cannot exceed 80K lbs, which is set forth by federal and state law enforcement. The revenue for any matching is proportional to the actual weight of trailer loaded on the truck. We study the problems of choosing weights/inventory levels for the trailers and the problem of developing a policy to optimally match these trailers to arriving trucks. We show that revenue management approximate DP techniques can be employed to solve all three of the previously mentioned problems.

#### 3 - An Approximate Dynamic Programming Approach to Queueing Admission Control Problems

Saied Samiedaluie, University of Alberta, 3-40C Business Building, Alberta School of Business, Edmonton, AB, T6G 2R6, Canada, Dan Zhang

We study a classical queueing control problem with multiple classes of customers. The queue is a loss system; i.e., arriving customers are rejected if all servers are busy. When a server is available, the decision is whether to admit an arriving customer and collect a lump-sum revenue. We model this problem as a continuous-time infinite-horizon dynamic program and solve it using approximate linear programming (ALP). We study several alternative approximation architectures and numerically investigate their policy performance. Our approach is potentially useful for a wide variety of queueing control problems.

#### 4 - An Approximate Dynamic Programming Approach to Dynamic Pricing for Network Revenue Management

Jiannan Ke, Shanghai Jiao Tong University, 1954 Huashan Road, Zhongyuan 111, Shanghai, 200030, China, Dan Zhang, Huan Zheng

We propose an approximate dynamic programming approach to the dynamic pricing problem for network revenue management. The approximate linear program (ALP) are semi-infinite linear programs and can be solved to any desired accuracy with a column generation algorithm. For the affine approximation under a linear independent demand model, we show that the ALP can be reformulated as a compact second order cone program (SOCP). The size of the SOCP formulation is linear in the number of resources, products, and periods. Numerical experiments show that solving the SOCP formulation is orders of magnitude faster and the ensuing pricing policies perform well.

### ■ SD23

North Bldg 131A

#### Statistical Methods in Finance

Sponsored: Finance

Sponsored Session

Chair: Markus Pelger, Stanford University, Stanford, CA, 94305, United States

##### 1 - Efficient Computational Methods for Distributionally Robust Optimization with Martingale Constraints

Jose Blanchet, Columbia University, 500 West 120th Street, 340 Mudd Building, New York, NY, 10027, United States

We study efficient distributionally robust optimization methods under martingale constraints. These problems arise in several OR applications, including.

##### 2 - Deep Learning Models of High Frequency Financial Data

Justin Sirignano, University of Illinois at Urbana-Champaign, 3 Gibbs Court, Irvine, CA, 92617, United States

Using a Deep Learning approach applied to a large dataset of high frequency financial data, we find evidence for a universal and stationary price formation mechanism relating the supply and demand for a stock, as revealed through the order book, to price dynamics. We build a 'universal price formation model' which demonstrates stable accuracy across a wide range of stocks from different sectors and for long time periods. The universal model, trained on data from all stocks, outperforms asset-specific linear and nonlinear models trained on time series of any given stock. This shows that the universal nature of price formation weighs in favor of pooling together financial data from various stocks, rather than designing asset- or sector-specific models as commonly done. We also find that price formation has path-dependence over long periods of time ('long memory'). Joint work with Rama Cont.

##### 3 - Statistical Inference using Neural-Networks

Enguerrand Horel, PhD Student, Stanford University, Stanford, CA, 94305, United States, Kay Giesecke

Although neural networks can provide highly accurate predictions, they are often considered as opaque "black boxes". The difficulty of interpreting the predictions of a neural network often prevents their use in financial practice, where regulators and auditors often insist on model explainability. In this project, we formulate the objectives of interpretability and define interpretability for neural networks. Then, by considering neural networks as nonparametric models, we show how to use nonparametric variable significance tests to assess the importance of covariates. Tests using mortgage data illustrate our results.

##### 4 - Interpretable Proximate Factors for Large Dimensions

Ruoxuan Xiong, Stanford University, 312 Huang Engineering Center, Stanford, CA, 94305, United States, Markus Pelger

This paper approximates latent statistical factors with sparse and easy-to-interpret proximate factors. Latent factors in a large-dimensional factor model can be estimated by principal component analysis, but are usually hard to interpret. By shrinking factor weights, we obtain proximate factors that are easier to interpret. We show that proximate factors consisting of 5-10% of the observations with the largest absolute loadings are usually sufficient to almost perfectly replicate the population factors without assuming a sparse structure. We derive lower bounds for the generalized correlation between proximate and population factors based on extreme value theory.

### ■ SD24

North Bldg 131B

#### eBusiness on Online Two-sided Market

Sponsored: EBusiness

Sponsored Session

Chair: Jinyang Zheng, Purdue University, West Lafayette, IN, 47906, United States

##### 1 - What Goes Around Comes Around: A Structural Matching Model of Peer-to-Peer Lending

Jinyang Zheng, Purdue University, West Lafayette, IN, 47906, United States, Yang Jiang, Xiangbin Yan, Yong Tan

Our work is the first empirical study that investigates the matching mechanism of online P2P lending. In this paper, we use data on transaction records from a large lending site, and apply a structural matching model to examine the determinants of a lender-borrower match formation. Our results show that the matching criteria differ across heterogeneous lenders and borrowers, depending on the interaction characteristics between the two sides. We provide evidence that a larger match value is associated with a better loan performance, which validates the effectiveness of the estimated matching pattern. Our findings shed lights on how to improve the matching efficiency of online two-sided markets.

##### 2 - Does Size Matter? The Effect of Sampling Size in Online Physical Good Sampling

Zibo Liu, University of Washington, Seattle, WA, 98195-5832, United States, Zhijie Lin, Ying Zhang, Yong Tan

Despite the popular use of product sampling as a promotional strategy by retailers, existing research has only studied offline sampling of physical goods and online sampling of information goods, but overlooked online sampling of physical goods. We argue that, in the context of online sampling of physical goods, sampling size serves as a signal of product quality to positively influence product sales, and this effect would vary across product type. We collected a panel-level data set from Taobao.com for empirical analysis. We find evidence for the existence of the effect of sampling size in online sampling of physical goods, and find that the effect indeed vary across products.

##### 3 - Consumer Decisions in Payment-based Knowledge Sharing Communities: The Analysis of Zhihu Live

Zhen Fang, University of Washington, Seattle, WA, 98195-5832, United States, Guannan Liu, Junjie Wu, Yong Tan

Knowledge monetization is becoming a new trend in knowledge sharing communities. Experts on platforms as Zhihu Live give payment-based lectures to audience in the community. This research empirically investigates the impact of different factors on the consumer decisions, including the price, communications, online reviews and the reputation of speakers in Q&A community, Zhihu. We conclude that lower price, more communication and higher reputation of the speaker improve the popularity of Lives.

### ■ SD25

North Bldg 131C

#### Service Science Topics in the IT Industry

Sponsored: Service Science

Sponsored Session

Chair: Aly Megahed, IBM Research - Almaden, San Jose, CA, 95123, United States

##### 1 - Will they Sign? Predicting the Contract Pipeline with Structured and Unstructured Data

Aly Megahed, IBM Research - Almaden, San Jose, CA, 95123, United States, Hamid Reza Motahari Nezhad, Paul R. Messinger

Suppliers of products and services often compete for highly-valued contracts in lengthy tender processes. Prediction of success for the various prospects in the pipeline is vital to managing a company's work flow. Toward this end, we develop a contract prediction model based on two kinds of data: structured deal attributes and unstructured text of seller comments. We show real-world numerical results that illustrate the effectiveness of our models. We also present managerial implications and insights of implementing this work for a real IT firm.

##### 2 - Analytics Driven Business Travel Management Solution

Pawan Chowdhary, IBM Research, 650 Harry Road, E3-238, San Jose, CA, 95120, United States, Raphael Arar, Guangjie Ren, Sunhwan Lee

Business travel is essential to meet customers and for the company to grow. Mid to large enterprise has business travel as one of the largest spend items but still not managed efficiently. IBM Travel Manager is a solution that is catered for the Travel Program Manager to effectively manage travel spend and leverage analytics to get spend insights and savings opportunities. In the presentation we will go few such analytics and touch over cognitive aspect that will drive the travel manager to act upon opportunities pro-actively.

**3 - Dynamic Cloud Capacity Planning**

Jon M. Stauffer, Texas A&M University, 4217 TAMU, College Station, TX, 77843, United States, Aly Megahed, Chelliah Srisankarajah, Ahmed Nazeem

Many companies are shifting from on-premise IT environments to cloud computing. The computing application resources (instances) need to be adjusted according to the demand (queries) over time. Determining the optimal number of instances needed in a given planning horizon is challenging due to the combinatorial nature of the optimization problem involved. Deploying too many instances results in unnecessary deployment/capacity costs, while deploying too few instances results in penalties for not being able to process all incoming queries on-time. We propose heuristics to solve the offline scheduling problem and illustrate their effectiveness in a real-world case study.

**■ SD26**

North Bldg 132A

**Undergraduate Operations Research Prize II**

Emerging Topic: Undergraduate Operations Research Prize

Emerging Topic Session

Chair: Jennifer A. Pazour, Rensselaer Polytechnic Institute, 110 8th street, CII 5217, Troy, NY, 12180, United States

**1 - Evolving Contact Network Algorithm: A New Simulation Method for Modeling HIV, a Disease with Low Prevalence but a Critical Public Health Issue in the US**

Matthew Eden, University of Massachusetts-Amherst, Amherst, MA, United States, Buyannemekh Munkhbat, Chaitra Gopalappa, Hari Balasubramanian

Agent-based network modeling (ABNM) is suitable for simulating multiple interacting events, related to contact network structures, behavior, and care access, for predicting epidemic trajectories. However, ABNM is infeasible to use for HIV due to disproportionate HIV prevalence across population groups in the US. We present a new modeling technique, evolving contact network algorithm (ECNA). Numerical results comparing ECNA with ABNM disease predictions are promising for low prevalence diseases.

**2- Limited-memory Kelley's Method Converges for Composite Convex and Submodular Objectives**

Swati Gupta, Georgia Institute of Technology, Atlanta, GA, United States

Original simplicial method (OSM) has been shown to converge to the minimizer of composite convex and submodular objectives, though no rate of convergence was known. Moreover, OSM is required to solve subproblems in each iteration whose size grows linearly in the number of iterations. We propose L-KM, a novel limited memory version of OSM that maintains convergence to the optimum. We show that the dual method of L-KM is a special case of the Fully-Corrective Frank-Wolfe (FCFW) method with approximate correction, thereby deriving a limited memory version of FCFW (holds for general polytopes) and proving a rate of convergence L-KM.

**3 - Assortment Optimization for a Multi-Stage Choice Model**

Yunzong Xu, Tsinghua University, Beijing, China, Zizhuo Wang

Motivated by several practical selling scenarios that require previous purchases to unlock future options, we consider a multi-stage assortment optimization problem, where the seller makes sequential assortment decisions with commitment, and the customer makes sequential choices to maximize her expected utility. We show that this problem is polynomial-time solvable when the customer is fully myopic or fully forward-looking. The optimal policy entails that the assortment in each stage is revenue-ordered and a product with higher revenue always leads to a wider range of future options. We also show that the problem is NP-hard in general and give efficient algorithms for various scenarios.

**■ SD27**

North Bldg 132B

**Student-centered Experiential Education: Learning by Doing**

Sponsored: Education (INFORMED)

Sponsored Session

Chair: Chun-Miin Chen, Bucknell University, Lewisburg, PA, 17837, United States

**1 - The Capstone Experience in Business Analytics Programs**

Andrew Urbaczewski, University of Denver, Daniels College of Business 593, 2101 S. University Boulevard, Denver, CO, 80208, United States

This session will show experiential learning opportunities at both the undergraduate and graduate levels of the Business Analytics Programs at the University of Denver. Recruitment, NDA, delivery, and feedback will all be discussed.

**2 - Introduction to Reverse Auctions: The BucknellAuto Game**

Chun-Miin Chen, Bucknell University, 95 Sunnyside Dr., Lewisburg, PA, 17837, United States

This article presents a spreadsheet-based game, the BucknellAuto game, that simulates the bidding process in a reverse auction. The BucknellAuto game serves as a pedagogical tool for efficiently and effectively introducing the reverse auction to undergraduate students in a fun and interactive way.

**3 - Optimization scheduling for Bobcat Pizza: An Optimization Experiential Learning for Service Management**

Iddrisu Awudu, Quinnipiac University, Hamden, CT, 06514, United States, David Boison

In this experiential learning experience, students consider a pizza making place (Bobcat Pizza) on a university campus. Students develop a simple optimization scheduling approach using excel as the main driver. The aim of this optimization scheduling is to enhance worker schedules to maintain a competitive urge for Bobcat Pizza over its competitors in the areas of local flavor and quality ingredients while implementing a system that minimizes wasted resources. Students collect data over a period of when the class was taught and proffered solutions for the said organization.

**■ SD28**

North Bldg 221A

**RAS Roundtable: Horsepower-hour in Today's Railway**

Sponsored: Railway Applications

Sponsored Session

Chair: Michael F. Gorman, University of Dayton, Dayton, OH, 45469, United States

Co-Chair: Shantih Marie Spanton, CSX, CSX, Jacksonville, FL, 32204, United States

**1 - Roundtable: Horsepower-hour in Today's Railway**

Shantih Marie Spanton, CSX, Jacksonville, FL, 32204, United States

Railroads may define locomotive work performed over time in terms of horsepower-hours. This term is primarily used in the context of the work of locomotives shared between railroads, wherein the horsepower-hours of a locomotive used by another railroad must be reimbursed to the owner. The balancing the horsepower-hours owed to a foreign carrier with usage of a railroad's own locomotive power is an interesting problem that raises both tactical and strategic questions. In this panel experts from several leading US rail carriers will discuss the impact of balancing horsepower-hours in today's cost sensitive environment, including issues of fleet sizing, fleet mix (foreign or system), tactical/seasonal balancing strategies, rules and regulations around horsepower balancing in the US system, and more.

**Panelists**

Grant Metcalf, Kansas City Southern RR, Kansas city, MO, United States

Kim Archer, CSX, CSX, Jacksonville, FL, 32201, United States

Jermaine Wilkinson, Norfolk Southern Corporation, Norfolk Southern Corporation, Norfolk, VA, United States

Ted Smith, BNSF, BNSF, Ft. Worth, TX, United States

**■ SD29**

North Bldg 221B

**Demand and Revenue Management in Urban Transportation**

Sponsored: TSL/Urban Transportation

Sponsored Session

Chair: Xinchang Wang, Mississippi State University, Mississippi State, MS, 39762, United States

**1 - Management of Shuttle Systems with Modular Vehicles under Oversaturated Demand**

Xiaopeng Li, University of South Florida, Eng 207, Tampa, FL, 33620, United States, Zhiwei Chen, Xuesong Zhou

In this paper, we investigate the joint design problem of dispatch headway and vehicle capacity for one to one shuttle systems considering oversaturated demand. The first model we proposed is a mixed integer linear programming model that



can yield exact solutions to the optimal design with a customized dynamic programming algorithm, where a series of valid inequalities based on the relationship between passenger demand and vehicle capacity are applied to expedite the solution speed. The second model is a continuum approximation (CA) model that presents a macroscopic view of the system and yields simple analytical rules into the optimal design.

## 2 - Optimal Rebalancing for Bike Sharing Systems with Information Assisted Riders

Mohammad Javad Feizollahi, Assistant Professor, Georgia State University, 35 Broad St., Room 408, Atlanta, GA, 30303, United States, Xinchang Wang

We consider a bike sharing system with riders who are well informed of the number of available bikes and dockers at each docking station. Meanwhile, this information affects the likelihood of riders choosing a station to pick up or drop off bikes. A fleet of homogeneous trucks is employed to reposition bikes between the stations. The objective is to minimize the sum of the bike rebalancing cost and the lost demand penalty cost. We focus on the static version of the problem and formulate it as a mixed-integer nonlinear program. To solve the program, we develop solution approaches leveraging techniques from both dynamic programming and discrete optimization. Our solutions are tested with numerical studies.

## 3 - Optimal Capacity Sizing of Park-and-ride Lots when Parking Availability Information is Publicized

Xinchang Wang, Mississippi State University, Marketing Department, 324C McCool Hall; Mailstop: 9582, Mississippi State, MS, 39762, United States, Qie He

We study the optimal capacity sizing of parking lots for park-and-ride commuters when parking availability information is publicized. Commuters' choice of parking lots follows a multinomial logit model accounting for the effects of road congestion and parking availability information. The objective is to maximize the total social welfare of all park-and-ride commuters. The problem is formulated as a stylized non-convex optimization model with the choice model. We provide a characterization of the optimal capacities with homogeneous routes. For the general case, we develop an efficient search algorithm to solve the model.

## 4 - A Multiplayer Parking Pricing Problem for Emerging On-line Markets

Hossein Fotouhi, George Mason University, 4630 Buckhorn Ridge, Fairfax, VA, 22030, United States, Elise Miller-Hooks

A bi-level, multi-player, parking pricing problem is presented. In the upper level, competing parking operators seek to maximize their revenue, while in the lower level users seek to minimize their parking choice disutility. The problem is formulated as an Equilibrium Problem with Equilibrium Constraints (EPEC). A heuristic algorithm is presented based on a concept of Nash domination.

## ■ SD30

North Bldg 221C

### Drone-assisted Logistics

Sponsored: TSL/Facility Logistics

Sponsored Session

Chair: Mehdi Behrooz, Northeastern University, Boston, MA, United States

## 1 - On Travelling Salesman Problems with Drone-truck Synchronizations

Minh Hoang H, PhD, University of Engineering and Technology, Vietnam National University, Hanoi, Viet Nam

In this talk, we will study two variants of travelling salesman problems with drone-truck synchronizations. In the first variant, while visiting a customer to provide a delivery, truck can launch a drone to service other customers, then continue to visit other customers before retrieving the drone at another customer location. In the second variant, truck arrives at a location and launches several drones to service customers. It has to stay there to retrieve all the drones before visiting other locations. Mathematical formulations, solution approaches and result discussions are presented.

## 2 - A Multi-modal Drone Delivery System for Urban Logistics

Mohammad Moshref-Javadi, Massachusetts Institute of Technology, 1 Amherst St, E40-247A, Cambridge, MA, 02142, United States, Ahmad Hemmati, Matthias Winkenbach

We present a mathematical formulation and heuristic solution approach for the optimal planning of last-mile delivery routes in a customer-centric, multi-modal urban logistics system combining truck and UAV-based delivery operations. The mathematical model and heuristic solution approach are applied to several generated and adapted problem instances from the literature. Further, we consider a real-world case study for e-commerce deliveries in Brazil.

## 3 - Integrated Pickup and Delivery Operations using Trucks and Drones

Nawin Yanpirat, Auburn University, Auburn, AL, United States, Daniel F. Silva, Alice E. Smith

We study optimal routing to perform both delivery and pickup operations with a single truck, outfitted with a single UAV, that it can deploy en-route to reach some drone-enabled customers. On each sortie, the drone can perform a single delivery operation, a single pickup or a delivery followed by a pickup. We model the problem as a mixed integer program and perform numerical experiments to measure the benefit to total route time of incorporating pickup operations. We also discuss the effects of battery life, drone speed and ratio of pickup to delivery customers on the total route time.

## 4 - The Multi Visit Drone Routing Problem

Stefan Poikonen, Assistant Professor, University of Colorado Denver, 1475 Lawrence Street, Denver, CO, 80202, United States

Many papers have considered hybrid truck-and-drone delivery models. Often they assume there is a single drone per truck, each package is homogeneous, the drone is capable of carrying one package at a time, the set of feasible launch locations is restricted to customer locations, and the drone has a fixed time battery life. In the Multi-visit Drone Routing Problem, we consider the case of a heterogeneous set of packages, a drone that is capable of carrying multiple packages at a time, a more flexible launch site set, and a user-defined energy drain function, which specifies the energy expenditure required by a drone to carry a given set of packages. Heuristics tractable for large instances will be presented.

## 5 - Travelling Salesman Problem with Drones

Mehdi Behrooz, Northeastern University, Department of Mech. & Ind. Engineering, 334 Snell Engineering Center, Boston, MA, 02115, United States, Dinghao Ma, Reyhaneh Mohammadi

Unmanned Aerial Vehicles (UAVs), commonly known as drones, have opened up their way into the massive industry of parcel delivery. In this paper, we study a travelling salesman problem with a drone in which a drone is dispatched from a delivery truck and while the truck is delivering the packages, the drone can also deliver a package and return to the truck after each delivery to pick up the next package. We present optimization models and heuristics to solve this problem. We show that the combination of a truck and a drone provides a much more efficient last-mile delivery service when compared to the truck-only delivery option under reasonable assumptions for the ratio of the speeds of the drone and the truck.

## ■ SD31

North Bldg 222A

### Innovative Transportation Data

Sponsored: TSL/Intelligent Transportation Systems (ITS)

Sponsored Session

Chair: Zhen Qian, Carnegie Mellon University, China

Co-Chair: Shanjia Zhu, George Mason University, Fairfax, VA, 22030, United States

## 1 - Understanding Ride-sourcing Drivers' Customer Search Behaviors

Zhengtian Xu, University of Michigan, 2489 Stone Rd, Ann Arbor, MI, 48105-2540, United States, Yafeng Yin

Ride-sourcing services have become increasingly important in meeting travel needs in metropolitan areas. Even though extensive studies were conducted to advance our understanding for such an emerging service, few of them paid attention to drivers' behaviors, partially due to the lack of related datasets disclosed by ride-sourcing companies. By leveraging the empirical evidences from Didi Chuxing, this study aims to comprehensively survey ride-sourcing drivers' decision making on customer search. We will investigate how drivers' search behaviors are interacted with different factors, and provide insights for ride-sourcing companies in managing drivers' labor supply.

## 2 - Measuring and Optimizing the Network Disequilibrium Levels through Ridesourced Vehicle Data

Wei Ma, Carnegie Mellon University, Pittsburgh, PA, 15213, United States, Zhen Qian

With the boom of the mobile internet, on-demand ride sourcing services such as Uber, are becoming an indispensable component of urban transportation systems. This research proposes a novel measure of network disequilibrium level with ridesourced vehicle data. It also proposes an information disclosure scheme such that the transportation networking companies are able to disclose the traffic information to benefit the public society without leaking the commercial confidential. A real-time NDL based routing method under the proposed information disclosure scheme to reduce total network congestion. Two large-scale real networks with disaggregated and aggregated ridesourced vehicle data.

### 3 - Trip Purpose Inference and Prediction with Social Media Data and Google Places

Yu Cui, University at Buffalo, The State University of New York,  
314 Bell Hall, Buffalo, NY, 14260, United States, Chuishi Meng,  
Qing He, Jing Gao

This research has addressed the problem of trip purpose prediction with both Google Places and social media data. First, this paper provides a new approach to match Point of Interests (POIs) from Google Places API with historical Twitter data. Therefore, the popularity of each POI can be obtained. Moreover, a Bayesian neural network (BNN) is employed to model the trip dependence within each individual's daily trip chain and infer the trip purpose.

### 4 - Quantifying Disruption Impact Across Transportation Networks

Priyadarshan Patil, The University of Texas at Austin, Austin, TX,  
United States, Steve Boyles, William Alexander

This research quantifies the propagation of impact on a transportation network, caused by a disruption on the network. We propose to model the impact using explanatory variables such as network characteristics, flow patterns, and link interactions. A classical statistical regression-based approach is contrasted with a method based on neural networks, applied and evaluated on real-world urban networks along with megaregional networks. The results assist in resource allocation and rapid response to network disruptions.

## ■ SD32

North Bldg 222B

### Joint Session TSL/MIF: Sustainable City Logistics – Improving Efficiency of Movement of Freight

Sponsored: TSL/Freight Transportation & Logistics

Sponsored Session

Chair: Diana Gineth Ramirez-Rios, Rensselaer Polytechnic Institute,  
Troy, NY, 12180, United States

#### 1 - Assessing Impacts of Emerging Market and Technological Trends for Freight-efficient Land-uses

Sofia Perez-Guzman, Rensselaer Polytechnic Institute, Troy, NY,  
12180, United States, Jose Holguin-Veras, Diana Gineth Ramirez-  
Rios, Juvena Ng, Wilfredo Yushimito Del Valle, Joshua Schmid

This study proposes an assessment of market trends and emerging technologies, and how the impacts brought by these disruptors affect the planning of freight-efficient land uses. To this extent, an evaluation framework was developed, which incorporates how trends affect decisions of stakeholders involved in different supply chains. The framework systematically captures each one of the decisions made by stakeholders based on the minimization of their total social costs (i.e. private costs and externalities) and translates these into short and long-term effects and land-use measures.

#### 2 - A Spatial Methodology for Characterizing Freight in Metropolitan Areas on the US

Carlos Rivera-Gonzalez, Rensselaer Polytechnic Institute, Troy, NY,  
United States, Jose Holguin-Veras, Juvena Ng,  
Diana Gineth Ramirez-Rios

This study proposes an innovative spatial methodology for understanding the economic activities in Metropolitan Statistical Areas (MSAs). Through the development of a spatial index and the incorporation of freight activity estimated at a ZIP code level, the study was able to identify freight activity clusters and freight corridors that could be useful for the decisions on the allocation of facilities in different urban settings. The analysis responds to a selected group of MSAs in the United States that represent a diversity of urban areas in terms of size and geographic location.

#### 3 - State of the Art and Practice of Urban Freight Management

Johanna Amaya Leal, Iowa State University, 2167 Union Drive,  
Room 3127, Ames, IA, 50011, United States, Jose Holguin-Veras,  
Ivan Sanchez-Diaz, Michael Browne, Jeffrey Wojtowicz

This paper conducts a review of the public-sector initiatives that could be used to improve freight activity in metropolitan areas; collects data about initiatives that have been implemented and their performance; and produces a ranking of suggested initiatives. The characterization and performance of the initiatives was based on a survey that collected data from countries and cities throughout the world. The paper ends with a discussion of chief findings.

#### 4 - Patrol Police Routing

Ruben Yie, Universidad el Norte, Km 5 Antigua via Puerto  
Colombia, Barranquilla, Colombia, Andrea Margarita Ditta

It is well-known that police patrolling is one of the best preventive practices for public safety against urban crimes. This work, deals with the problem of planning police patrol routes to minimize the overall risk at minimum cost. A specific mathematical formulation, models the problem under critical time constraints and resources. Algorithms of ant colony and evolutionary techniques, offers effective solutions for this model. A case study in Barranquilla (Colombia), allows validate the performance of our approach in real scenarios.

## ■ SD33

North Bldg 222C

### George B Dantzig Dissertation Prize I

Emerging Topic: George B Dantzig Dissertation Prize

Emerging Topic Session

Chair: Mor Armony, New York University, 44 West 4th Street #8-62,  
New York, NY, 10012, United States

#### 1 - Models and Algorithms for Transportation in the Sharing Economy

Daniel Freund, Cornell University, Ithaca, NY, USA.

This thesis consist of two parts. The first deals with bike-sharing systems which are now ubiquitous across the U.S.A. We have worked with Motivate, the operator of the systems in, for example, New York City, Chicago, and San Francisco, to innovate a data-driven approach to managing both their day-to-day operations and to provide insight on several central issues in the design of their systems. This work required the development of a number of new optimization models, characterizing their mathematical structure, and using this insight in designing algorithms to solve them. Many of these projects have been fully implemented to improve the design, rebalancing, and maintenance of Motivate's systems across the country.

#### 2 - Optimization and Machine Learning Methods for Diagnostic Testing of Prostate Cancer

Selin Merdan, PhD Candidate, University of Michigan,  
Ann Arbor, MI, USA.

Technological advances in biomarkers and imaging tests are creating new avenues to advance precision health for early detection of cancer. These advances have resulted in multiple layers of information that can be used to make clinical decisions, but how to best use these multiple sources of information is a challenging engineering problem due to the high cost and imperfect sensitivity and specificity of these tests. Questions that need to be addressed include which diagnostic tests to choose and how to best integrate them, in order to optimally balance the competing goals of early disease detection and minimal cost and harm from unnecessary testing. To study these research questions, we present new optimization-based models and data-driven analytic methods in three parts to improve early detection of prostate cancer (PCA).

#### 3 - Latent Variable Model Estimation via Collaborative Filtering

Christina Lee Yu, Cornell University, Ithaca, NY, USA.

Similarity based collaborative filtering for matrix completion is a popular heuristic that has been used widely across industry in the previous decades to build recommendation systems, due to its simplicity and scalability. However, despite its popularity, there has been little theoretical foundation explaining its widespread success. In this thesis, we prove theoretical guarantees for collaborative filtering under a nonparametric latent variable model, which arises from the natural property of "exchangeability", i.e. invariance under relabeling of the dataset. The analysis suggests that similarity based collaborative filtering can be viewed as kernel regression for latent variable models, where the features are not directly observed and the kernel must be estimated from the data. In addition, while classical collaborative filtering typically requires a dense dataset, this thesis proposes a new collaborative filtering algorithm which compares larger radius neighborhoods of data to compute similarities, and show that the estimate converges even for very sparse datasets, which has implications towards sparse graphon estimation.

## ■ SD34

North Bldg 223

### 4:30 - 5:15 Elsevier/5:15 - 6:00 Wayfair

Vendor Demo Session

#### 1 - How to Get Published and Meet the Editors Session

Simon Jones, Elsevier, Oxford, United Kingdom

How to get Published in Operations Research Journals addresses how to prepare and submit a manuscript using correct manuscript language, and how to structure an article.

#### 2 - Geo-Testing for Real-World Marketing

Nathan Vierling-Claassen, Wayfair, Boston, MA, United States

Optimized geographic testing is becoming a popular method for measuring the value of marketing interventions that are not amenable to more standard controlled testing methods, but getting the method to work in a real-world business environment is not always straightforward. This tutorial, we will give an overview of geo-testing methods at Wayfair. Using e-commerce marketing as a case study, we will cover practical approaches including:

When & why to choose geo-testing as opposed to other more standard techniques. Test design & optimization to generate national results from local tests. Quantifying & avoiding "geo-leakage". Test design methods for cost reduction while retaining statistical power.

## ■ SD35

North Bldg 224A

### UAS and Aviation Forecast

Sponsored: Aviation Applications

Sponsored Session

Chair: Chia-Mei Liu, Federal Aviation Administration, Washington, DC, 20591, United States

#### 1 - Airline Network Evolution Forecasting

Reed Harder, Dartmouth, 14 Engineering Drive, Hanover, NH, 03755, United States, Vikrant Vaze

Airline networks evolve as airlines enter and exit various markets and routes. Accurate modeling of this evolution would allow for better forecasting of airport activity and more effective long-term planning by decision makers in the air transportation system. However, forecasting airline network evolution remains a challenge because of the complicated, interdependent nature of available data and the relative sparsity of entry and exit events. We present approaches for the probabilistic modeling of airline network evolution that leverage multiple sources of information on potential market and route entries.

#### 2 - Unmanned Aircraft System (UAS) National Forecast in the U.S.

Bhadra Dipasis, Federal Aviation Administration

Abstract not available.

#### 3 - Air Route Traffic Control Center (ARTCC) Operation Forecast

David Hechtman, Senior Modeling and Simulation Engineer, The MITRE Corporation, 7515 Colshire Drive, McLean, VA, 22102-7539, United States, Michael Yablonski, Ricky Marske

The FAA Office of Aviation Policy and Plans requested that The MITRE Corporation develop a forecasting method for Air Route Traffic Control Center (ARTCC) operations using an origin-and-destination (O-D) passenger demand framework. FAA's Terminal Area Forecast-Modernization (TAF-M) predicts O-D segment demand but not ARTCC operations. To provide this information, MITRE developed a TAF-based ARTCC forecast incorporating O-D segment demand from TAF-M and historical routing data from the FAA Traffic Flow Management System.

#### 4 - The Effect of Oil Price Pass Through Rate on U.S. Domestic Airfare Forecast

Chia-Mei Liu, Federal Aviation Administration, 800 Independence Avenue SW, Washington, DC, 20591, United States, Kang Hua Cao

FAA publishes Terminal Area Forecast (TAF) annually. TAF includes enplanement and operation forecasts for all U.S. airports. Among the heavily traveled airports, FAA also publishes optimistic and pessimistic forecasts to quantify forecast uncertainty. One important driver for the forecast uncertainty is the uncertainty in oil price, which leads to the uncertainty in airfares and enplanements subsequently. This research studies airlines' ability to pass oil price change to the consumers by raising or reducing airfares. We control for factors such as airline competition and economic activities to quantify the airfare elasticity with respect to oil price change.

## ■ SD36

North Bldg 224B

### Joint Session AAS/Practice Curated: Aviation Applications Section: Awards Finalists

Sponsored: Aviation Applications

Sponsored Session

Chair: Vikrant Vaze, Dartmouth College, 14 Engineering Drive, Murdough Center, Hanover, NH, 03755, United States

#### 1 - Aviation Applications Section: Awards Finalists

## ■ SD37

North Bldg 225A

### APS Student Paper Competition

Sponsored: Applied Probability

Sponsored Session

Chair: John Hasenbein, University of Texas-Austin, 1 University Station Stop C2200, Department of Mechanical Engineering, Austin, TX, 78712-0292, United States

#### 1 - Adaptive Learning with Unknown Information Flows

Ahmadreza Momeni, Stanford University, Stanford, CA, 94025, United States

We introduce a generalized multi-armed bandit formulation in which additional information on each arm may appear arbitrarily throughout the decision horizon,

and study the impact of such information on the achievable performance and the design of efficient decision-making policies. We characterize the regret complexity of this family of problems and introduce a general and practical adaptive exploration approach for designing policies that, without any knowledge on the information arrival process, attain the best performance that is achievable when that arrival process is a priori known.

#### 2 - Stochastic Game for Fuel Follower Problem: N vs MFG

Renyuan Xu, University of California-Berkeley, 4141 Etcheverry Hall, OR Department, Berkeley, CA, 94720, United States

In general, finding a Nash equilibrium (NE) or proving Pareto optimality (PO) for continuous-time stochastic game with multiple players is hard, even when there are only two players in the game. Mean Field Game (MFG) provides a powerful tool and analytically feasible framework to approximate the NE and the PO of the N-player stochastic games. In this talk, we will first define the stochastic game for the classical fuel follower problem in the seminal paper by Benes, Shepp, and Witsenhausen (1980). We will then solve and compare with explicit solutions for the NE and the PO of the N-player game, and the corresponding MFG when the number of players goes to infinity. This is a joint work with Xin Guo (UC Berkeley).

#### 3 - Statistics of Robust Optimization: A Generalized Empirical Likelihood Approach

Hongseok Namkoong, Stanford University, Stanford, CA, 94305, United States

We study statistical inference and distributionally robust solution methods for stochastic optimization problems, focusing on confidence intervals for optimal values and solutions that achieve exact coverage. We develop a generalized empirical likelihood framework—based on distributional uncertainty sets constructed from nonparametric f-divergence balls—for Hadamard differentiable functionals, and in particular, stochastic optimization problems. Our theory prescribes the robustness level that provide one- and two-sided confidence intervals that achieve exact coverage.

#### 4 - SOAP: One Clean Analysis of All Age-Based Scheduling Policies

Ziv Scully, Carnegie Mellon University, 5000 Forbes Avenue, GHC 7121, Pittsburgh, PA, 15213, United States

We consider an extremely broad class of M/G/1 scheduling policies called SOAP: Schedule Ordered by Age-based Priority. The SOAP policies include most policies in the literature as well as infinitely many variants which have never been analyzed. SOAP policies range from classic policies, like first-come, first-serve (FCFS), foreground-background (FB), class-based priority, and shortest remaining processing time (SRPT); to much more complicated scheduling rules, such as the famously complex Gittins index policy and shortest expected remaining processing time (SERPT). We present a universal analysis of all SOAP policies, deriving the mean and Laplace-Stieltjes transform of response time.

## ■ SD38

North Bldg 225B

### Stochastic Models for the Blockchain

Sponsored: Applied Probability

Sponsored Session

Chair: Ciamac Cyrus Moallemi, Columbia University, New York, NY, 10027, United States

Co-Chair: Jacob Leshno, Columbia University, New York, NY, 10027, United States

#### 1 - Bitcoin: A Natural Oligopoly

Nicholas A. Arnosti, Columbia Business School, 3022 Broadway, Uris Hall rm 402, New York, NY, 10027, United States

Although Bitcoin was intended to be a decentralized digital currency, in practice, mining power is quite concentrated. This fact is a persistent source of concern for the Bitcoin community. We provide an explanation using a simple model to capture miners' incentives to invest in equipment. In our model, n miners compete for a prize of fixed size. Each miner chooses an investment level, incurring cost proportional to their investment. Miners receive rewards proportional to their investment. We show that seemingly small cost differences result in highly concentrated mining power, and discuss the implications of our results for cryptocurrency design.

#### 2 - Scaling Cryptocurrency Blockchains

Rhys Bowden, Rhys Bowden, Anthony Krzesinski, Peter G. Taylor

Cryptocurrency blockchains form the globally distributed ledgers of their associated cryptocurrencies. A blockchain is updated at random intervals, when a miner adds a new block (referencing the most recent block they have heard about) on to the end of the chain, then that block is communicated to the other miners and the rest of the network as a whole. Typically the time taken to communicate a new block is much less than the average time between blocks arriving. We model this process to show how the system functions when blocks arrive so frequently that consensus is rare.



### 3 - The Economics of Bitcoin

Ciamac Cyrus Moallemi, Columbia University, Columbia Business School, 3022 Broadway Uris 416, New York, NY, 10027, United States, Gur Huberman, Jacob Leshno

The Bitcoin payment system is a platform with two main constituencies: users, who make and receive payments; and profit-seeking miners, who maintain the system's infrastructure. We seek to understand the economics of the system: How does the system raise revenue to pay for its infrastructure? How are usage fees determined? How much infrastructure is deployed? What are the implications of changing parameters in the protocol? To address these questions, we offer and analyze an economic model of a cryptocurrency system featuring user-generated transaction fees, and focus on Bitcoin as the leading example. The analysis leads to design suggestions for future cryptocurrencies.

## ■ SD39

North Bldg 226A

### Markov Decision Processes

Sponsored: Applied Probability

Sponsored Session

Chair: Daniel Silva, Auburn University, Auburn, AL

#### 1 - Pooled Dynamic Matching in Freight Networks

Ankur Mani, University of Minnesota, Saint Paul, MN, 55114, United States

We study online matching of trucks to shipments over a geographic network. We evaluate the impact of pooling and flexibility of truck drivers on the size of the matching and total welfare. Surprisingly, by only allowing truck drivers to submit their top two preferences, nearly optimal matching can be guaranteed with very high probability. In the dynamic setting, when shipment demands arrive everyday, a small fraction of flexible drivers can increase the total welfare significantly.

#### 2 - Reannealing for Exploration in Deep Q-networks

Xing Wang, Auburn University, Auburn, AL, 36830, United States, Alexander Vinel

Existing exploration strategies in reinforcement learning (RL) often either ignore the history or feedback of search, or are complicated to implement. There is also a very limited literature showing their effectiveness over diverse domains. We propose an algorithm based on the idea of reannealing, that aims at encouraging exploration only when it is needed, for example, when the algorithm detects that the agent is stuck in a local optima. The approach is simple to implement, and the experimental results have shown effectiveness of our exploration strategy on accelerating training procedure as well as obtaining a better policy on hard RL problems.

#### 3 - Optimal Pricing for Tandem Queues with Finite Buffers

Xinchang Wang, Mississippi State University, Marketing Department, 324C McCool Hall; Mailstop: 9582, Mississippi State, MS, 39762, United States, Sigrun Andradottir, Ayhan Hayriye

We consider optimal pricing for a two-station tandem queueing system with finite buffers. The service provider quotes prices to incoming customers using either static or dynamic pricing. The objective is to maximize either the infinite-horizon discounted profit or the long-run average profit. We show that there exists an optimal dynamic policy that exhibits an interesting monotone structure, in which the quoted prices have greater dependency on the queue length at station 1 than at station 2. We show that the optimal static policy performs as well as the optimal dynamic policy for the long-run average problem when the buffer size at station 1 becomes large and the arrival rate is either small or large.

#### 4 - Easy Decomposable Markov Decision Processes

Jie Ning, Case Western Reserve University, Department of Operations, 328 Peter B. Lewis Building, Cleveland, OH, 44106, United States

We characterize a special class of Markov decision processes (MDPs) called easy decomposable MDPs. These MDPs have vector-valued continuous endogenous states and actions and a set of feasible actions that are decomposable and are independent of the endogenous state. The expected single-period reward and dynamical equations have special structures that allow an analytical characterization of the value function and an optimal policy. Particularly, we show that the value function and optimal policy depend on the solution of a set of auxiliary equations which depend only on the exogenous state. Finally, we give examples of this class of easy decomposable MDPs.

#### 5 - Optimal Routing in Loss Systems with Flexible Customers

Avnish Malde, Clemson University, Clemson, SC, United States, Tugce Isik

We study a loss system with two classes of servers and a multiple customer types. We assume that there is at least one class of flexible customers that can receive service from servers of either type. We formulate the problem as a Markov decision process with rewards that are dependent on the customer type. For small systems, we use our formulation to characterize the policies that maximize the long-run average reward. For larger systems, we study the structure of the

optimal policies. Our analysis shows that the optimal policies are structured, and of threshold type. We also provide an application of our model and numerical examples in the context of electric vehicle charging.

## ■ SD40

North Bldg 226B

### Stochastic Systems

Sponsored: Applied Probability

Sponsored Session

Chair: Mark S. Squillante, IBM Thomas J. Watson Research Center, Yorktown Heights, NY, 10598, United States

#### 1 - On Stochastic Gradient Descent for Distributionally Robust Optimization (DRO)

Soumyadip Ghosh, IBM TJ Watson Research Center, 1101 Kitchawan Road, Route 134, Yorktown Heights, NY, 10598, United States, Mark S. Squillante, Ebisa D. Wollega

Current approaches to DRO do not scale well because of the high dimensionality of the decision variable of the probability mass function (pmf) over the entire dataset. We propose a new SGD algorithm to efficiently solve these min-max formulations. In each iteration, we approximate the optimization over the uncertainty set by sub-sampling the support, where the size of the sub-sample is itself generated from another pmf. We develop asymptotic guarantees on how this procedure optimally balances, in a strong statistical sense, the computational effort with the required level of accuracy.

#### 2 - Distributionally Robust Optimal Bidding in Online Advertising

Jose Blanchet, Stanford University, CA, United States

We study practical and easy to implement distributionally robust optimal bidding strategies for online advertising in the context of first price auctions in which the bidder has imperfect information.

#### 3 - Functional Cumulant Moments

William A. Massey, Princeton University, ORFE Department, Sherrerd Hall, Princeton, NJ, 08544, United States, Jamol Pender

Given a specific measurable real-valued function, functional cumulant moments of a random variable, when appropriately defined, are a new but complementary variation on cumulant moments. We demonstrate their utility to Markovian queueing systems by applying these functional moments to the cumulant moments of birth-death process. These results have applications to the steady state analysis of some given time-homogeneous queueing models as well as the transient behavior of their time-inhomogeneous counterparts.

#### 4 - On Density-dependent Population Processes with Time-varying Behavior

Mark S. Squillante, IBM Research, 1101 Kitchawan Road, Yorktown Heights, NY, 10598, United States, Yingdong Lu, Chai W. Wu

We consider density-dependent population processes and the control of such stochastic processes, both with time-varying parameters. Such behaviors are of mathematical interest in general, and can be especially important and arise often in many existing and emerging applications.

## ■ SD41

North Bldg 226C

### Making Good Decisions

Sponsored: Decision Analysis

Sponsored Session

Chair: Johannes Siebert, MCI

#### 1 - Explaining Proactive Decision Making

Reinhard Kunz, Philipp Rolf

The Proactive Decision Making scale, which is based on the concepts of value-focused thinking and decision quality, measures proactive personality traits and cognitive skills in decision-making. Using SEM, we show that proactive cognitive skills can explain up to 36% of life satisfaction, i.e. proactive decision makers are more satisfied with their decisions and with their lives. Furthermore, we provide empirical evidence that proactive cognitive skills can be trained in a course on decision-making. We recommend schools, colleges, and universities to offer more courses on decision-making to enhance student's proactive cognitive skills and satisfaction with their decisions and lives.

## 2 - Constructing a Value Model for an Organization

Ralph L. Keeney, Duke University, CA, United States

Constructing an organizational value model provides a foundation to build agreement on the organization's objectives and to guide consistent decision-making among all important decisions. The concepts, process, and procedures to construct an organizational value model are discussed and illustrated using a value model constructed for the US Army Corps of Engineers.

## 3 - The Costs and Benefits of Homeland Security Research

Delfot von Winterfeldt, CA, United States

Since 2004 the U.S. Department of Homeland Security's Office of University Programs has funded close to half a billion dollars on research, resulting in over two hundred research products, including software tools and other technologies. We evaluated the costs and benefits of selected research products, showing a high rate of return on this investment.

## 4 - Exploring Benefits of Value-focused Brainstorming Based on Associative Network Model

Chen Wang, Tsinghua University, Beijing, China, Ying Xiang

Generating alternatives is crucial for making good decisions. We propose an empirical method that helps examine the ability of decision makers to generate effective alternatives and the impact of objective-related stimuli. We apply machine learning methods to construct the cognitive map of a brainstorming exercise by projecting key words of the group discussion onto a latent cognition space. We then measure the degrees of exploitation and exploration for the alternative-generation process and demonstrate the benefits of value-focused brainstorming using recorded data.

## ■ SD42

North Bldg 227A

### Joint Session ISim/Practice Curated: Simulation Modeling Applications

Sponsored: Simulation

Sponsored Session

Chair: Mohammad Dehghanimohammadabadi, Northeastern University, Boston, MA

#### 1 - Estimating the Real Demand in Bike-Sharing Systems

Ashkan Negahban, Pennsylvania State University, 30 E. Swedesford Rd, Malvern, PA, 19355, United States

The objective of the first part of this presentation is to: (1) provide a formal comparison between the distribution of bike-inter pickup times and the underlying (latent) customer inter-arrival time; and, (2) propose an alternative data filtering method to improve demand estimation by preserving the portion of the observed bike inter-pickup times that represent actual customer inter-arrival times. The second part introduces an iterative methodology combining simulation, nonparameteric bootstrapping, and indifference-zone analysis to estimate the true demand in bike-sharing systems when data analysis approaches fail.

#### 2 - Introducing an Efficient Way to Optimize a Simulated Model with Data-table Inputs

Mohammad Dehghanimohammadabadi, Northeastern University, 170 Brookline Avenue, Unit 1025, Boston, MA, 02115, United States

The major goal in simulation-optimization studies is to obtain the most appropriate configuration settings of the model. This could be easily achieved via embedded optimizers in simulation packages such as OptQuest. However, these optimizers fail to optimize the simulation models designed based on data-table inputs. This study extends the boundaries of the existing simulation-optimization tools by incorporating data-tables as a control parameter of the simulation model. This new approach could significantly enhance the applicability of the simulation and reduce efforts to optimize data-table driven simulation models.

#### 3 - An Agent-based Model of Individual Forgetting and Learning Behavior in Epidemics

Kaiming Bi, Kansas State University, 1605 Roof Drive, Manhattan, KS, 66502, United States, Yuyang Chen, Chih-Hang Wu, David Ben-Arieh

We presents two mathematical models, information forgetting curve (IFC) model and memory reception fadingcumulating (MRFC) model, to examine forgetting and learning behaviors of individuals during an epidemic. Both models consider behavior-change information may affect agent emotions and subsequently influence an individual's behavior. IFC model utilizes a forgetting curve to process epidemic information, and MRFC model formulates disease information variations using the It process. An agent-based simulation model also developed to mimic the epidemic prevalence of the 2009 Chicago H1N1.

## ■ SD43

North Bldg 227B

### Energy and Climate I

Emerging Topic: Energy and Climate

Emerging Topic Session

Chair: Peter Larsen, Lawrence Berkeley National Laboratory, Berkeley, CA, 94720, United States

#### 1 - Integrated Modelling Tool for Electricity Rate Design in Systems with High Penetration of DERs

Miguel Heleno, Lawrence Berkeley National Laboratory, Berkeley, CA, United States

This talk presents a modeling tool to support decision-making for electricity system planning and retail rate design in the context of distribution grids with high penetration of distributed energy resources (DERs). This tool is based on an interaction between two layers of optimization: the first, representing end-users, aims at finding the optimal behind-the-meter DER adoption; the second, representing the system operation, determines the optimal portfolio of utility assets that mitigates the impact of DERs deployment and ensures the steady state operation of the distribution grid.

#### 2 - Drivers of the Reliability Contribution of Solar+Storage for Utilities in Florida

Andrew Mills, Lawrence Berkeley National Lab., 1 Cyclotron Red, Uc Berkeley, CA, 94720, United States

Abstract not available.

#### 3 - Evaluating the Economics of Power Interruptions and Investments in Resilience

Peter Larsen, Lawrence Berkeley National Laboratory, 1 Cyclotron Road, MS 90-4000, Berkeley, CA, 94720, United States

This presentation will introduce and elaborate on a number of U.S. government-sponsored projects that explore the economics of power interruptions and investments that mitigate cyber security threats and other risks to U.S. power system reliability and resilience.

#### 1 - The Regional Economic Accounting Tool: A Demonstration of Updates and Extensions

Vanessa Vargas, Sandia National Laboratories, Albuquerque, NM, United States

The Regional Economic Accounting tool (REAct) was developed by economists at Sandia National Laboratories (SNL) for estimating order-of-magnitude economic impacts within scenario/real-time analysis. REAct uses input-output modeling, geo-spatial data computational tools, and publicly available economic data to estimate the impacts of disruptive events and allows for detailed specification of sectors, regions, and disruption intervals. There are a number of improved capabilities for REAct, including seasonal impact analyses, improved indirect impact estimation, and a proxy for economic system resilience. System resilience is related to a system's ability to absorb, adapt, and recover from a disruptive event. Studies of past disruptive events indicate that factors which affect an economic system's ability to recover can vary across regions, industries, or even firms in the same industry. We have established a preliminary method for incorporating resilience based on firm and industry characteristics in regions affected during an acute disruptive event. Incorporating quarterly data into the analysis helps tailor the results of analyses both to current economic conditions and economies with seasonal production. This paper details the changes to REAct and provides a demonstration of the tool for specific geographies.

## ■ SD44

North Bldg 227C

**Stability and Solvability of Power Flow Systems**

Sponsored: Energy, Natural Res &amp; the Environment/Electricity

Sponsored Session

Chair: Andy Sun, Georgia Institute of Technology, Atlanta, GA, 30312, United States

Co-Chair: Konstantin Turitsyn, Massachusetts Institute of Technology, Cambridge, MA, 02139, United States

**1 - Load-flow in Multiphase Distribution Networks: Existence, Uniqueness, Non-singularity, and Linear Models**

Andrey Bernstein, Senior Scientist, National Renewable Energy Laboratory (NREL), Golden, CO, United States

We consider unbalanced multiphase distribution systems with generic topology, and extend the Z-bus iterative load-flow algorithm based on a fixed-point interpretation of the AC load-flow equations. Explicit conditions for existence and uniqueness of load-flow solutions are presented, guaranteeing convergence of the load-flow algorithm to the unique solution. The methodology is applicable to generic systems featuring wye connections, ungrounded delta connections, and a combination thereof. A sufficient condition for the non-singularity of the load-flow Jacobian is proposed. Linear load-flow models are derived, and their approximation accuracy is analyzed.

**2 - A Theory of Solvability for Lossless Power Flow Equations**

John W. Simpson-Porco, Assistant Professor, University of Waterloo, Waterloo, ON, Canada

This talk presents a theory of solvability for power flow equations in lossless networks. We formulate a new model of power flow, termed the fixed-point power flow (FPPF), which is parameterized by three graph matrices quantifying the internal coupling strength of the network. The FPPF leads to an explicit approximation of the high-voltage solution. For a subclass of acyclic networks, we derive necessary and sufficient parametric conditions for the existence of a power flow solution which is unique within a specified set, generalizing the classic textbook result for a two-bus system.

**3 - Convex Restriction of Power Flow Feasibility Set**

Dongchan Lee, Massachusetts Institute of Technology, Cambridge, MA, United States, Hung Nguyen, Krishnamurthy Dvijotham, Konstantin Turitsyn

Convex restriction of the power flow feasibility set identifies the convex subset of power injections where the solution of power flow is guaranteed to exist and satisfy the operational constraints. In contrast to convex relaxation, convex restriction provides a sufficient condition for feasibility and is particularly useful for problems addressing uncertainty and security analysis. In this talk, we present a general framework of constructing convex restriction of an algebraic set and apply the framework for power flow feasibility problem. The results provide a nearly tight approximation of the actual feasible set for many of the IEEE test cases.

## ■ SD45

North Bldg 228A

**Joint Session ORAM/CYBER: Cyber Manufacturing Systems: Emerging Challenges and Opportunities**

Emerging Topic: OR and Advanced Manufacturing

Chair: Mohammed Shafae, University of Arizona, Tucson, AZ, USA.

**1 - Challenges and Opportunities in Additive Manufacturing for Industry 4.0**

Bianca Maria Colosimo, Politecnico di Milano, Milan, Italy.

This contribution discusses opportunities and challenges for quality assessment, monitoring and control of Additive Manufacturing (AM) processes and products. Special attention is devoted to in-situ data gathering and modeling.

**2 - Advancing the Security of Cybermanufacturing Systems: Challenges and Opportunities**

Lee Wells, Western Michigan University, Portage, MI, USA, Mohammed Shafae

As technology progresses, cyber-physical systems are becoming susceptible to a wider range of attacks. In manufacturing, these attacks pose a significant threat to ensuring products conform to their original design intent and to maintaining the safety of equipment, employees, and consumers. This talk discusses the importance of research and development of cyber-security tools specifically designed for manufacturing. A critical review of current research efforts will be presented as well as opportunities for the future of this emerging research area.

**3 - Blockchain in Manufacturing – A Critical Review**

Soundar Kumara, Pennsylvania State University, PA, USA

Blockchain is becoming popular in several domains. In this talk we explore the technical foundations of Blockchain and their applicability in (big-M) manufacturing. We will discuss provenance, platforms and the relevance of blockchain. With specific example in manufacturing, we will explore the integrated use of blockchain-analytics and AI. We will address the questions on hyperledger and Ethereum platforms.

## ■ SD46

North Bldg 228B

**Electricity Market Modeling**

Sponsored: Energy, Natural Res &amp; the Environment/Energy

Sponsored Session

Chair: Steven A. Gabriel, University of Maryland, College Park, MD, 20742-3021, United States

Co-Chair: Ben Hobbs, Johns Hopkins University, Baltimore, MD, United States

**1 - Pricing Environmental Externalities in Regions with Asymmetrical Policies**

Robin Broder Hytowitz, Johns Hopkins University, Baltimore, MD, 21201, United States, Benjamin Field Hobbs

We examine integration of regional carbon policies into multi-regional real-time electricity markets, as is the case with California's cap-and-trade system and Energy Imbalance Market. Five methods for dispatch and pricing are compared. Findings suggest that there is a trade-off between emissions and cost, with no one dominant method to identify and manage carbon leakage from the region with a carbon policy.

**2 - Market Power under Nodal and Zonal Congestion Management Techniques**

Mette Bjørndal, NHH Norwegian School of Economics, Helleveien 30, Bergen, 5045, Norway, Endre Bjørndal, Somayeh Rahimi Alangi, Linda Rud

European electricity day-ahead markets use simplified methods such as uniform or zonal pricing, which only partly address congestion. Re-dispatch is then necessary to achieve a feasible flow. We discuss that simplified methods (e.g. uniform pricing) combined with re-dispatch, in theory can achieve the maximum optimal surplus, however this only occurs under the assumptions of full participation in re-dispatch and no extra costs of readjustment. We show that violations of these assumptions, i.e. limited participation and extra costs of readjustment can make the day-ahead and re-dispatch model of handling congestion inefficient compared to nodal pricing.

**3 - Convex Hull Pricing in Power Markets: Recent Developments in Theory, Computational Efficiency and Practice**

Peter Whitman, Federal Energy Regulatory Commission, 10808 Gainsborough Road, Potomac, MD, 20854-2510, United States

All power markets have non-convexities which make efficient, transparent pricing challenging. Given the changing conditions in power markets, there is renewed interest in Convex Hull Pricing (CHP). An approximation of CHP (ELMP) has been implemented for fast-start resources in the Midcontinent Independent System Operator (MISO), and it has been discussed in other markets. This paper reviews the rationale for CHP and summarizes some key theorems. In particular, it discusses the characterization and role of side payments, reviews revenue adequacy, and explains approximations that make solutions computationally feasible.

**4 - A Price-based Bidding Strategy for Electric Storage Resources in Electricity Markets**

Qingyu Xu, Johns Hopkins University, Baltimore, MD, 21218, United States, Nikita Singhal, Erik Ela

FERC Order 841 requires the ISOs to remove the barriers that prevent electric storage resources (ESRs) to enter electricity markets. During the process, instead of proposing direct managing the state of charge (SoC) of ESRs, several ISOs provide ESRs with the option to manage their own SoC through their offers. In this work, using price signals, we formulate a MILP to bid offer curves for ESRs 1) to maximize the profits from arbitraging energy and providing ancillary services, meanwhile 2) to maintain the SoC feasibility when dispatched by ISO, who is not aware of ESR's SoC information.



## ■ SD47

North Bldg 229A

### Joint Session Tutorial/Practice Curated: Machine Learning and Data Mining with Combinatorial Optimization Algorithms

Emerging Topic: Practice Curated Track

Emerging Topic Session

Chair: Scott J. Mason, Clemson University, 273 Freeman Hall, Clemson, SC, 29634, United States

#### 1 - Machine Learning and Data Mining with Combinatorial Optimization Algorithms

Dorit Simona Hochbaum, University of California-Berkeley, Dept of IEOR, 4135 Etcheverry Hall MC 177, Berkeley, CA, 94720-1777, United States

The dominant algorithms for machine learning tasks fall most often in the realm of AI or continuous optimization of intractable problems. This tutorial presents combinatorial algorithms for machine learning, data mining, and image segmentation that, unlike the majority of existing machine learning methods, utilize pairwise similarities. These algorithms are efficient and reduce the classification problem to a network flow problem on a graph. One of these algorithms addresses the problem of finding a cluster that is as dissimilar as possible from the complement, while having as much similarity as possible within the cluster. These two objectives are combined either as a ratio or with linear weights. This problem is a variant of normalized cut, which is intractable. The problem and the polynomial-time algorithm solving it are called HNC. It is demonstrated here, via an extensive empirical study, that incorporating the use of pairwise similarities improves accuracy of classification and clustering. However, a drawback of the use of similarities is the quadratic rate of growth in the size of the data. A methodology called "sparse computation" has been devised to address and eliminate this quadratic growth. It is demonstrated that the technique of "sparse computation" enables the scalability of similarity-based algorithms to very large-scale data sets while maintaining high levels of accuracy. We demonstrate several applications of variants of HNC for data mining, medical imaging, and image segmentation tasks, including a recent one in which HNC is among the top performing methods in a benchmark for cell identification in calcium imaging movies for neuroscience brain research.

## ■ SD48

North Bldg 229B

### Joint Session ENRE/Practice Curated: Wildland Fire Decision Support I

Sponsored: Energy, Natural Res & the Environment Forestry

Sponsored Session

Chair: Yu Wei, Colorado State University, Fort Collins, CO, 80523, United States

#### 1 - Identify and Present Large Fire Containment Strategies

Yu Wei, Colorado State University, Department of FRWS, Forestry 102, Fort Collins, CO, 80523, United States, Matt Thompson

Catastrophic large wildfire could threaten human lives, properties and natural resources. Fire containment involves complicated decisions. We build an OR model to use stochastic fire simulation results to support large fire suppression effort. Instead of selecting only one optimal suppression strategy, our analyses provide a range of "good fire containment strategies based on a wide range of fire situation predictions, manager's risk preferences, resource availability levels, and other management restrictions. Model results lead to alternative suppression solutions that are organized through decision-trees to support fast decisions during a fire event.

#### 2 - A Decision Support System for Dispatching Interagency Hotshot Crews

Erin Belval, Colorado State University, 1472 Campus Delivery, Fort Collins, CO, 80523, United States, Dave E. Calkin, Yu Wei, Crystal S. Stonesifer, Alex Taylor Masarie

Interagency Hotshot Crews (IHCs) are an important wildland fire suppression resource. During the fire season, they drive long distances to respond to ongoing and emerging fires; previous research has indicated that this driving could be reduced. We spent the summer of 2018 working with dispatchers to refine an existing optimization model to produce 1) a real-time dispatching tool and 2) a model that uses historical data to realistically examine the impacts on IHCs of changing various policies. In this presentation we discuss the process of refining the model with dispatching input, the current state of the real-time tool, and some results from the model utilizing historical data.

#### 3 - Evaluating Alternative Models for Evaluating the Daily Deployment of Airtankers for Forest Fire Suppression

David L. Martell, University of Toronto, Faculty of Forestry, 33 Willcocks Street, Toronto, ON, M5S 3B3, Canada

Forest fire management agencies often use airtankers to assist with initial attack on fires and as is the case with other emergency response systems, response time is crucial. Each day the regional duty officer must decide where to deploy his or her airtankers to minimize their expected response time given the predicted fire arrival rates. Resolution of the daily airtanker deployment problem calls for the design and control of a complex spatial queueing system with time-dependant arrival rates and complex service processes. We explore the merits of using alternative simplified initial attack process models to evaluate daily airtanker deployment strategies.

## ■ SD49

North Bldg 230

### Optimization and Systems Engineering Methods in Petrochemicals and Energy

Sponsored: Energy, Natural Res & the Environment/Natural Resources Petrochemicals

Sponsored Session

Chair: Christos T. Maravelias, University of Wisconsin-Madison, Madison, WI, 53706, United States

#### 1 - Minimum Number of Matches in Heat Recovery Networks for Energy Efficiency

Georgia Kouyialis, Imperial College London, London, United Kingdom, Dimitrios Letsios, Ruth Misener

Heat exchanger network synthesis exploits excess heat by integrating process hot and cold streams and improves energy efficiency by reducing utility usage. Determining provably good solutions to the minimum number of matches problem is a bottleneck of designing a heat recovery network. This subproblem is an NP-hard mixed-integer linear program (MILP). We (i) explore this MILP from a graph theoretic perspective, (ii) discuss its symmetric properties, (iii) develop heuristic methods with performance guarantees, and (iv) develop a new MILP formulation without big-M parameters for special cases. Numerical results from a collection of 51 instances substantiate the methods.

#### 2 - Solving Mixed-integer Linear Bi-level Optimization Problems through an Augmented Lagrangean Method

Francisco Trespalacios, ExxonMobil Research & Engineering, Clinton, NJ, United States, Stuart M. Harwood, Dimitri Papageorgiou, Myun-Seok Cheon

In this work, we present a model that demonstrates the relevance of bi-level optimization in the energy industry. Then, we present a novel method for solving mixed-integer linear bi-level optimization problems by using the Augmented Lagrangean of the subproblem. Finally, we present numerical examples that demonstrate the efficiency of this method against other methods.

#### 3 - Integration of Crude-oil Scheduling and Refinery Planning by Lagrangean Decomposition

David E. Bernal, Carnegie Mellon University, Carnegie Mellon University, Pittsburgh, PA, 15213, United States, Haokun Yang, Ignacio E. Grossmann

We address the optimization of integrated refinery problem, involving crude oil scheduling and refinery operation planning. We study several modeling approaches for the Crude Distillation Unit (CDU): fixed yield, swing cuts, fractionation index. Our model, which solves both the scheduling and planning simultaneously with linking constraints for the CDU, is compared against a non-integrated approach to the crude oil scheduling and followed by the refinery planning. Furthermore, we present a Lagrangean Decomposition algorithm for this problem, whose solution time is compared versus the case that the monolithically integrated model is solved using state-of-the-art MINLP solvers.

#### 4 - Combining the Advantages of Discrete- and Continuous-time MIP Scheduling Models

Christos T. Maravelias, University of Wisconsin-Madison, 1415 Engineering Drive, Engineering Hall 2024, Madison, WI, 53706, United States, Ho Jae Lee

We develop a solution algorithm, for large-scale chemical production scheduling problems, that consists of three stages: (1) solution of a discrete-time models to obtain batching, task-unit assignment, and sequencing decisions; (2) mapping of solution, preserving the three aforementioned decisions, onto time grids; and (3) solution of an LP to obtain accurate solution based on the decisions made in the first stage. We also discuss how to use two algorithmic parameters to obtain good first-stage decisions, and how to model complex processing features. We close with an extensive computational study showing the effectiveness of the proposed algorithm.

## ■ SD50

North Bldg 231A

**Joint Session Practice/Practice Curated:  
Edelman Reprise II**

Sponsored: INFORMS Section on Practice (formerly CPMS)

Sponsored Session

Chair: Anne G. Robinson, Verizon Wireless, Basking Ridge, NJ, 07920, United States

Co-Chair: Carrie Beam, University of Arkansas, Fayetteville, AR, 94596, United States

**1 - Pediatric Heart Network**

Eva Lee, Georgia Tech, Industrial &amp; Systems Engineering, Ctr for Operations Research in Medicine, Atlanta, GA, 30332-0205, United States

The Pediatric Heart Network enlisted researchers with the Georgia Institute of Technology to create clinical practice guidelines (CPG) for pre-, intra-, and post-surgical care of patients with congenital heart defects (CHDs), the most common birth defect, impacting nearly 1 million children and 1.4 million adults in the U.S. Substantial variances in surgical practices to treat patients with CHDs among different healthcare centers were reflected in inconsistent surgical outcomes, some of which resulted in negative consequences for patients. By studying the nine leading U.S. pediatric centers, the researchers identified seven significant factors for influencing surgical outcome, and implemented a CPG that enables patients to be removed from breathing apparatuses earlier, lowered the rate of reintubation, and decreased the time patients need to remain in the intensive care unit. These guidelines also realized a cost savings of 27 percent, which translates to \$13,500 per patient.

**2 - Analytics Makes Inventory Planning A Lights-Out Activity at Intel Corporation**

Sean Willems, University of Tennessee, 617 Commodore Lane, Knoxville, TN, 37934, United States

Intel, which employs more than 100,000 people in over 70 countries around the world and has an annual revenue of \$60 billion, implemented a fully automated Multi-Echelon Inventory Optimization (MEIO) based inventory target-setting system managing \$1 billion daily in finished goods inventory representing over \$40B a year in sales. Algorithm-derived inventory targets at Intel are accepted by planners +99.5 percent of the time and have simultaneously driven higher customer service and lower inventory levels resulting in over \$1.3B in gross profit since 2014. In addition, customers are delighted: since MEIO was implemented at all of Intel's vendor managed inventory hubs in 2012, customer satisfaction has never been higher and Intel has landed in the top-10 of Gartner's Supply Chain Top-25 every year. Faculty in the department of Business Analytics and Statistics at the University of Tennessee, Knoxville and the supply chain software company Logility also contributed to this project.

## ■ SD51

North Bldg 231B

**Joint Session OMS/Practice Curated:  
Applied Scheduling**

Emerging Topic: Project Management and Scheduling, in Memory of Joe Leung,

Emerging Topic Session

Chair: Zhixin Liu, University of Michigan - Dearborn, 19000 Hubbard Dr, Dearborn, MI, 48126, United States

**1 - Scheduling Jobs on Mixed Batching Machines**

Guoqiang Fan, Northwestern Polytechnical University, 127 West Youyi Road, Xi'an, SN 29, China, Junqiang Wang

This paper considers a mixed batching model that is different from the parallel-batch and the serial-batch. The mixed batching machine can process at most  $b$  jobs simultaneously. The processing time of a batch is the weighted sum of the maximum processing time and the total processing time of the jobs in the batch. The objective is to minimize the makespan. We first prove that the Full Batch Longest Processing Time (FBLPT) algorithm yields an optimal schedule for the problem on a single mixed batching machine. Then we show the NP-hardness of the problem on parallel mixed batching machines. We analyze the worst-case ratio of FBLPT algorithm and a modified-FBLPT algorithm.

**2 - Introducing Swing Shifts to Dynamically Respond to Emergency Department Workload Uncertainty**

David L. Kaufman, University of Michigan - Dearborn, 19000 Hubbard Drive, Fairlane Center South, Dearborn, MI, 48126, United States, Kalyan Pasupathy, Daniel Cabrera, Mustafa Y. Sir

A fundamental problem of emergency care is matching resources to uncertain patient demands. Staffing allocation decisions require good matching with workloads but also consider the needs of emergency providers at very high risk of burnout. Mayo Clinic Emergency Department recently introduced a "swing shift," which allows physicians to leave early depending on a workload threshold. While popular, swing shifts introduce several challenges: How to design a threshold mechanism? What is the optimal length of the furlough? When should these shifts start and what is their impact? We introduce an effective and tractable data-driven optimization model for a complex stochastic problem.

**3 - Maximizing On-time Jobs for the Customer Order Scheduling Problem**

Hairong Zhao, Purdue University Northwest, 2200 169 Street, Hammond, IN, 46323, United States

We consider the problem of scheduling multi-task jobs on parallel machines. Each job consists of one or more tasks. Each job has a release date and a due date. A task of a job can be processed by any one of the machines. Multiple machines can process the tasks of a job concurrently. The objective is maximizing the number of on-time jobs. We show that while the general problem is NP-hard, some special cases are solvable. For the general case, we develop some heuristics whose performance is evaluated by experimental results.

**4 - Cost Allocation in Rescheduling with Machine Unavailable Period**

Zhixin Liu, University of Michigan-Dearborn, 19000 Hubbard Drive, Dearborn, MI, 48126-4100, United States, Liang Lu, Xiangtong Qi

We study a rescheduling problem faced by multiple jobs owners sharing a single machine, where jobs need to be rescheduled, when the machine becomes unavailable for a period. We define a feasible schedule over which cost saving can be achieved by optimal rescheduling, and then formulate a cooperative game for job owners accordingly, to share the cost saving. Given that the optimization problem is computationally intractable, we find several optimal properties and develop an optimal pseudopolynomial time dynamic programming algorithm for rescheduling. We provide a simple closed form core allocation of the total cost saving for all the jobs, and provide the Shapley value of the game in a computable form.

## ■ SD52

North Bldg 231C

**Social Media for Socially Responsible Operations**

Emerging Topic: Social Media Analytics

Emerging Topic Session

Chair: Moravec Tricia, IN, United States

Co-Chair: Alfonso Pedraza, Indiana University, Bloomington, IN, 47405, United States

**1 - Transparency in Crowdfunding for Emergency Management**

Gloria Urrea, Indiana University, Bloomington, IN, 47408, United States, Jorge Mejia, Alfonso J. Pedraza-Martinez

We study online crowdfunding as a tool to increase funding for emergency relief campaigns. Crowdfunding campaigns can use two tools to increase the transparency provided to potential donors: certification and online updates. Certification is a form of conventional transparency that ensures the campaign is benefiting a charitable purpose. Alternatively, updates are additional status posts and are a form of operational transparency when they communicate the work of the campaign. Using data from a large crowdfunding website, we show that work-related updates (operational transparency) have a stronger effect on increasing donations than certification (conventional transparency).

**2 - Matching Donors to Projects on Charitable Giving Platform**

Yicheng Song, University of Minnesota, Minneapolis, MN, United States, Zhuoxin Li, Nachiketa Sahoo

Matching donors with causes is critically important in philanthropy. We propose a donors-project match mechanism, considering donors' preferences, budget, and cognitive limitations as well as the dynamic status and budgetary needs of the projects. The proposed model better captures donation behavior than several benchmarks. Using the estimated model, we design optimal recommendation policies to maximize fundraising success. By matching projects to donors, not only based on the donors' preference, but also their budget, and their willingness to support projects with different odds of success, the optimal recommendation strategies increase the donations raised by about 22%.

### 3 - Competition and Coopetition among Social Media Content in Disasters

Eunae Yoo, University of Tennessee, Knoxville, TN, United States,  
Elliot Rabinovich, Bin Gu

Humanitarian organizations may convey similar content when communicating on social media platforms during disasters. Our study examines if the diffusion for a piece of content is detracted by or is augmented by the spread of similar content. Therefore, we test whether a competitive or coopetitive dynamic exists among similar content. To that end, we formulate a generalized Hawkes model and estimate the model using Twitter data from multiple disasters. The results from our analysis indicate that similar content tends to interact competitively. Based on the results, we provide implications for humanitarian organizations for coordinating the release of similar social media content during crises.

### 4 - Reducing Fear through Credible Information During Crisis

Tricia Moravec, Indiana University, Bloomington, IN, United States

The increase in global natural disasters and crises throughout the past 10 years, combined with the increased usage of online social media in transmitting information during these disasters, had led to increased need to understand the process through which social media enables at-risk people to stay informed. People panic in the face of a natural disaster, and the first method to enable rational response is to calm the public down. We examine whether information provided from one with an authoritative, reliable reputation helps people calm down, so they may more rationally deal with the crisis. We find that increased informational support does negatively influence fear, such that fear decreases when information is posted by the premier authority on wildfire fighting. Our results suggest that informational support is highly effective in enabling people to make the most effective decisions during the disaster response phase by helping them toward a more rationale state of mind.

## ■ SD53

North Bldg 232A

### Machine Learning in Market Design

Sponsored: Auction and Marketing Design

Sponsored Session

Chair: Sven Seuken, University of Zurich, Zurich, 8050, Switzerland

Co-Chair: Benjamin Lubin, Boston University, Boston, MA, 02215, United States

#### 1 - The Power of Machine Learning and Market Design for Cloud Computing Admission Control

Ludwig Dierks, University of Zurich, Zurich, Switzerland,  
Ian Kash, Sven Seuken

Cloud computing providers must handle customer workloads that wish to scale their use of resources such as virtual machines up and down over time. Currently, this is often done using simple threshold policies to reserve large parts of compute clusters, which leads to a low average utilization of the cluster. We present new, more sophisticated policies that can take learned or elicited probabilistic information about the future behaviors of arriving workloads into account. Based on these policies, we show the high potential machine learning and market design have for increasing efficiency.

#### 2 - Combinatorial Auctions via Machine Learning-based Preference Elicitation

Gianluca Brero, University of Zurich, Stettbachstrasse, 93, Zurich, 8051, Switzerland, Benjamin Lubin, Sven Seuken

Combinatorial auctions (CAs) are used to allocate items among bidders with complex valuations. Since the value space grows exponentially in the number of items, it is often impossible for bidders to report all their values, thus leading to inefficiencies. We introduce a machine learning-based elicitation algorithm to identify which values to query from the bidders. We integrate this algorithm in a new CA mechanism we call PVM where payments are determined so that bidders' incentives are aligned with allocative efficiency. We validate PVM experimentally and we show that it achieves high allocative efficiency even when only few values are elicited from the bidders.

#### 3 - A Bayesian Clearing Mechanism for Combinatorial Auctions

S. Bastien Lahaie, Google, New York, NY, 10011, United States,  
Gianluca Brero

We cast the problem of combinatorial auction design in a Bayesian framework to incorporate prior information into the auction process and minimize the number of rounds. We develop a generative model of bidder valuations and market prices, which then forms the basis of an auction process which alternates between refining estimates of bidder valuations, and computing candidate clearing prices. We provide an implementation of the auction, empirically evaluate it over a range of valuation domains, and find that it is extremely competitive against a conventional combinatorial clock auction.

### 4 - Learning to Branch for Winner Determination in Combinatorial Auctions

Tuomas W. Sandholm, Carnegie Mellon University, Gates Center for Computer Science, Pittsburgh, PA, 15213, United States,  
Maria Florina Balcan, Travis Dick, Ellen Vitercik

Tree search algorithms, e.g. branch-and-bound, are the most widely used tools for combinatorial/nonconvex problems - e.g. MIP/CSP. To get small trees, it is key to decide, when expanding a node, on which question (e.g. variable) to branch. Many techniques have been proposed, but theory was lacking. We show how to use machine learning to determine an optimal weighting of any set of branching rules for the instance distribution at hand using samples from the distribution. We prove the first sample complexity guarantees for tree search algorithm configuration. The theory gives rise to a learning algorithm. It dramatically reduces tree size, e.g. in optimal combinatorial auction winner determination.

## ■ SD54

North Bldg 232B

### Behavioral Research in Sustainability and Supply Chains

Sponsored: Behavioral Operations Management

Sponsored Session

Chair: Stephen Leider, University of Michigan, Ann Arbor, MI, 48109, United States

#### 1 - Relative Performance Transparency: Effects on Sustainable Consumer Behavior

Yanchong Zheng, MIT, Cambridge, MA, 02142, United States,  
Ryan Buell, Shwetha P. Mariadassou

We study how transparency into the levels and changes of relative sustainability performance affects consumer behavior. In a series of online consumer choice studies, we show that when the relative performance concerns comparison of a firm to its competitors, transparency into the firm's relative performance level has a stronger impact on behavior than transparency into the firm's relative performance change. Conversely, when concerning performance comparison of the consumer him/herself to other consumers, transparency into relative performance changes has a more dominant effect on behavior. We identify the mechanisms underlying these results and confirm them in our last study.

#### 2 - Shared Supplier Capacity as a Barrier to Socially Responsible Sourcing

Jacob Chestnut, Cornell College of Business, SHA, Ithaca, NY, United States, Ravi Anupindi

This experimental project considers the role of buyer behavior (e.g., time pressure, low margin, near delivery specification changes) in their supplier's performance along the dimension of social sustainability (forced OT, child labor, unauthorized outsourcing, etc.). We attempt to understand the relevant features (contractual and non-contractual) that suppliers use when creating a preference ranking over buyers. Doing so allows us to assess the effectiveness of the operational and non-operational levers that a "good buyer might employ to improve their rank, thereby decreasing the likelihood that deviations occur on their order.

#### 3 - The Role of Psychological Distance and Construal Level on Sustainable Operations Decision Making

Saif Mir, Assistant Professor, College of Charleston, Charleston, SC, 29424, United States, Stephanie Eckerd, John Aloysius

We evaluate the role of psychological distances and construal levels in influencing operations manager propensity to make sustainable decisions. Previous studies have largely investigated cases when the two mechanisms are congruent. Specifically, near psychological distances are linked with concrete construal and far psychological distances are linked with abstract construal. In our study we evaluate the interaction of these mechanisms and the resulting effect on decision making behavior, using a 2 (Psychological distance: Near/Far) x 2 (Construal level: High/Low) vignette experiment.

#### 4 - Building Alliances for Socially Responsible Sourcing

Han Zhang, Student, Kelley School of Business, Indiana University Bloomington, 1309 E. 10th St Ste 4100, Bloomington, IN, 47405, United States, Ruth Beer, Kyle D. Cattani

Following the mandate by the Dodd-Frank Act that US public companies disclose the use of conflict minerals in their products and processes, five well-known companies established a fund to audit mineral suppliers. This initiative has been a success at raising funds despite the incentives of companies to free ride on the contributions by other companies. Our game-theoretical model incorporates two elements that explain the phenomenon: an invitation stage and heterogeneity in the statuses of the firms. Our lab experiment shows that the invitation stage is key to high contributions, and status significantly influences whether the invitation succeeds.



## ■ SD55

North Bldg 232C

**Joint Session Sports/Practice Curated:  
Sports Analytics III**

Sponsored: SpORts

Sponsored Session

Chair: Keith A. Willoughby, University of Saskatchewan, Saskatoon, SK, S7N 5A7, Canada

**1 - Ratio Breakers: Analyzing Drafting Strategy in the Canadian Football League**

Keith A. Willoughby, University of Saskatchewan, Department of Finance and Management Science, Saskatoon, SK, S7N 5A7, Canada, Kent Kostuk

The Canadian Football League (CFL) deploys a "game rule ratio mandating that Canadian athletes comprise at least 21 members of a team's 44-player roster. This regulation requires team management to strategically evaluate Canadian talent in order to assemble competitive rosters. The primary source of Canadian player recruitment is the league's annual draft. We analyze over two decades of draft results and determine a number of insights to guide drafting strategies.

**2 - Modeling Extra Inning Decisions in Softball**

Kent J. Kostuk, Federated Co-Operatives Limited, 9 Cantlon Crescent, Saskatoon, SK, S7J 2T2, Canada, Keith A. Willoughby

In softball when teams are tied after the regulation 7th inning they continue to play additional innings to determine a winner. In an effort to reduce the number of extra innings, each half inning starts with a runner on 2nd base. A typical defensive philosophy is to always focus on preventing runners from advancing. Alternatively, offensively teams will typically bunt; sacrificing an out in an effort to improve the likelihood of scoring. We will develop a model that will allow us to quantify the efficacy of these classic defensive and offensive strategies.

**3 - Understanding the Female/male Velocity Ratio of Olympic Champions in Running, Speed Skating, Swimming and Rowing**  
Raymond Stefani, California State University, Long Beach, CA, United States

Photographs of male and female Olympic champions taken about 80 years apart show little change in physiology but major changes in the competitive conditions that would increase efficiency. Thus, if both genders are now equally trained and equally efficient, then performance ratios should depend on physiology ratios, which are likely to have changed little. Equations are derived from physiology and physics for which power times efficiency depends on performance, physiology and other factors common to both genders. Assuming equal training and efficiency, the velocity ratio of female/male Olympic champions simplify when populated with kinesiology data from over 2000 athletes in the various types of competition. The velocity ratio for running and speed skating is estimated to be the relative lean-to-weight (LTW) ratio while for swimming and rowing the estimate is the 8/9 power of the relative LTW ratio. The approach appears to be validated in that, for 1992-2016, elite female athletes had 90% of the lean-to-weight ratio that men had and, in fact, their Olympic champions ran, swam and rowed about 90% as fast. For 1980 to 2014, in speed skating, elite female athletes had 92% of the lean-to-weight ratio of men and their Olympic champions skated 92% as fast.

**4 - Predictive Power of the (1, a) Method Compared to Traditional Sports Ranking Methods**

Baback Vaziri, James Madison University, 2210 Reserve Circle, Unit 203, Rockingham, VA, 22801, United States, Shaunak Dabaghao

Ideally, a ranking method for a sports tournament will be not only fair and comprehensive, but it will also possess strong predictive power. In a recent article, the (1, a) method was proposed as being fair and comprehensive in comparison with other popular sports ranking methods. In this study, we compare the predictive power of the (1, a) method against five (5) popular sports ranking methods for NFL, NHL and NBA seasons from 2001-2015. We also show which values of a are best suited for the (1, a) method to maximize the methods' predictive power based on sport.

**5 - Effects of Major League Baseball Manager Attributes on Team Performance**

Seong Dae Kim, Associate Professor, University of Tennessee at Chattanooga, Chattanooga, TN, 37403, United States, J.C. Kim

For the 2017 season, an average salary of the top-5 highest-paid managers is a \$4.5 M. 4 out of 5 managers are employed with teams located in large cities. Many of them have a lot of experience as a manager and are highly paid. But hiring an experienced manager could be a difficult decision to teams in small markets. Teams may want to consider hiring a more affordable and less experienced but promising young manager to save money to hire good players. To address this problem, this study analyzes data sets about MLB managers using data analytics techniques to explore the effects of the manager's attributes on the team performance. This study will help MLB teams hire a right manager with a tight budget.

## ■ SD56

West Bldg 101A

**Social Interactions in the Sharing Economy**

Sponsored: Manufacturing &amp; Service Oper Mgmt/Supply Chain

Sponsored Session

Chair: Laurens G. Debo, Dartmouth College, Hanover, NH, 03755, United States

Co-Chair: Guangwen Kong

**1 - Blockbuster or Niche? Competitive Strategy under Network Effects**

Ming Hu, University of Toronto, Rotman School of Management, 105 St. George Street, Toronto, ON, M5S 3E6, Canada, Yinbo Feng

We provide a theory that unifies the long tail and blockbuster phenomena. We show analytically that a growing network effect always contributes to more sales concentration on a small number of products, supporting the blockbuster phenomenon. However, product variety and investments in quality, as an outcome of firms' ex ante competitive decisions, may increase or decrease, as the network effect grows.

**2 - The Leverage from Family and Friends: Manage Outside Funds in a Crowd-funding though Inside**

Behrooz Pourghannad, University of Minnesota, Minneapolis, MN, 55414, United States, Guangwen Kong, Laurens G. Debo

We study how an entrepreneur can use the funds from her social network, i.e. her family and friends, during his crowd-funding campaign. We investigate how the investment from family and friends may impact on the amount of investment that entrepreneur could seek, and how reciprocities play a role in revealing the information of a crowd-funding campaign.

**3 - Strategic Surge Pricing and Forecast Communication in On-demand Service Platforms**

Harish Guda, University of Texas-Dallas, 2700 Waterview Parkway, #4424, Richardson, TX, 75080, United States, Upender Subramanian

We examine pricing and communication strategies of on-demand service platforms, explicitly accounting for the platform's and workers' incentives to serve consumers in adjacent market zones. We show when, how and why surge pricing may be counterintuitively used even in zones where supply exceeds demand to further imbalance supply and demand.

**4 - Choosing the Optimal Campaign Mode in Reward Based Crowdfunding**

Simone Marinesi, Assistant Professor of Operations Management, The Wharton School, University of Pennsylvania, Philadelphia, PA, 19103, United States, Ekaterina Astashkina, Karan Girotra

We compare two alternative campaign modes for rewards-based crowdfunding campaigns, Fixed Funding and Flexible Funding. In contrast to prior literature, which argues that Fixed Funding is superior to Flexible Funding, we show that each campaign mode can outperform the other, depending on the characteristics of the project, and we provide recommendations for how to choose between the two.

## ■ SD57

West Bldg 101B

**New Advances in Appointment Scheduling and Online Resource Allocation**

Sponsored: Health Applications

Sponsored Session

Chair: Mark P. Van Oyen, University of Michigan, Ann Arbor, MI, 48109-2117, United States

Co-Chair: Esmaeil Keyvanshokoh, University of Michigan-Ann Arbor, Ann Arbor, MI, 48108-1020, United States

**1 - Prioritizing Access to Hepatitis C Treatment in U.S. Prisons**

Turgay Ayer, Georgia Institute of Technology, School of Industrial and Systems Engineering, Groseclose 417, Atlanta, GA, 30332, United States, Can Zhang, Anthony Bonifonte, Jagpreet Chhatwal, Anne Spaulding

HCV prevalence in prison systems is ten times higher than the general population, and hence prison systems offer a unique opportunity to control the HCV epidemic. New HCV treatment drugs are very effective, but providing treatment to all inmates is prohibitively expensive. As such, current practice recommends prioritizing treatment based on clinical and incarceration-related factors. However, there is controversy about how these factors should be incorporated because of the complicated tradeoffs. In this study, we propose a restless bandit modeling framework to support hepatitis C treatment prioritization decisions in U.S. prisons.

## 2 - Impact of Mobile Technologies on Health Outcomes for Patients with Chronic Disease

Leon Cui, Binghamton University, 62 Decatur St, Binghamton, NY, 13903, United States, Sal Agnihothri, Balaraman Rajan, Mohammad Delasay

Chronic conditions place a high cost burden on the healthcare system and deplete the quality of life for millions of Americans. Mobile technologies can be used to provide efficient and effective healthcare. We attempt to evaluate the impact of using these technologies on health outcomes for patients with chronic disease.

## 3 - Managing Appointment-based Services in the Presence of Walk-in Patients

Shan Wang, Shanghai Jiao Tong University, Xuhui District, 1954 Huashan Road, Shanghai, 200030, China, Nan Liu, Guohua Wan

We study how to manage daily operations of a healthcare facility that accepts both scheduled and walk-in patients. In particular, we develop a data-driven optimization approach to determine the optimal appointment schedule in the presence of potential walk-ins. Our approach can handle highly complex environments with general walk-in processes and heterogeneous, time-dependent patient no-show behaviors. Using data from practice, we predict a significant cost reduction (42%-73% on average) if the providers were to switch from current practice (which tends to ignore walk-ins in planning) to our proposed schedules.

## 4 - Advance Online Scheduling with Overtime:

### A Primal-Dual Approach

Esmaeil Keyvanshokoh, University of Michigan-Ann Arbor, Ann Arbor, MI, 48108-1020, United States, Cong Shi, Mark P. Van Oyen

We study an online advance scheduling problem with reward and service time heterogeneity as well as budgeted overtime in which patients arrive one by one. Upon each arriving patient, the scheduler chooses both a resource and a day over a planning horizon without any information on the subsequent patients. By solving an online linear program, we design online optimization algorithms for this purpose and prove a worst-case performance guarantee. A case study of outpatient clinic scheduling is conducted.

## SD58

West Bldg 101C

## Improving the Allocation of Donor Organs

Sponsored: Health Applications

Sponsored Session

Chair: Burhaneddin Sandikci, University of Chicago, Chicago, IL, 60637, United States

Co-Chair: Sait Tunc, University of Chicago, Chicago, IL, 60637, United States

## 1 - Size Based Exception Points for Fair Liver Allocation

Mustafa Akan, Carnegie Mellon University, 5000 Forbes Ave. Posner 381C, Pittsburgh, PA, 15213, United States, Musa Celdir, Sridhar R. Tayur

Patients on the waiting list for liver transplants receive priority based on their Model for End-Stage Liver Disease (MELD) scores, which reflect the severity of liver disease. Recent studies have shown that for patients with Hepatocellular Carcinoma (HCC), shorter candidates and women (which may relate to smaller stature) have longer wait times and lower probability of liver transplant. Using a queueing model and data from the Scientific Registry of Transplant Recipients (SRTS), we investigate whether additional MELD exception points would help equalize the size-based disparity in organ access.

## 2 - Delay Aware Allocation Policies in Kidney Allocation Systems

Chaithanya Bandi, Kellogg School of Management, Northwestern University, 2211 Campus Dr, room 4169, Evanston, IL, 60208, United States

We investigate the problem of designing fair and delay aware allocation policies for the Kidney Allocation systems. We formulate the problem as a Robust Queueing control problem and present various structural results.

## 3 - Incentivized Kidney Exchange

M. Utlu Unver, Boston College, Chestnut Hill, MA, 02467, United States, Tayfun Sonmez, Bumin Yenmez, Bumin Yenmez

Over the last 15 years, kidney exchange has become a mainstream paradigm to increase transplants. However, compatible pairs do not participate, and the full benefits from exchange can be realized only if they do. We propose incentivizing compatible pairs to participate in exchange by insuring their patients against future renal failure via increased priority in the deceased-donor queue. Efficiency and equity analyses of this scheme are conducted and compared with that of kidney exchange in a new dynamic continuum model. We calibrate the model with US data and quantify substantial gains from adopting incentivized exchange in efficiency and access equity.

## 4 - Treating to the Priority in Heart Transplantation

Sait Tunc, University of Chicago, McGiffert House 4th Floor, 5751 S. Woodlawn Avenue, Chicago, IL, 60637, United States, Burhaneddin Sandikci, Philipp Afeche, William Parker

US heart allocation system assigns priorities to waiting candidates based on the therapies they receive, where the severity of therapies used is assumed to measure the urgency of a candidate to receive a heart transplant. It is, however, constantly debated that therapy-based prioritization opens up room for gaming the system. We propose a novel framework to analytically study the gaming decisions of heart transplant centers, understand when strategic gaming emerges under different competition types, and how it can be prevented within the confines of the current system.

## SD59

West Bldg 102A

## Managing Capacity of Surgical and Procedural Areas

Sponsored: Health Applications

Sponsored Session

Chair: Vikram Tiwari, Vanderbilt University Medical Center, Nashville, TN, 37221, United States

Co-Chair: Joonyup Eun, Vanderbilt University Medical Center, Nashville, TN, 1211 21st Avenue South, Room 708, Nashville, TN, 37212, United States

## 1 - Influence of Patient Experience and Shared Decision-making on Surgical Scheduling

Franklin Dexter, University of Iowa, Department of Anesthesia, Division of Management Consulting, Iowa City, IA, 52242, United States

We surveyed patients' perceptions of the service being provided by elective surgery, and desire to share in the decision of scheduling. Most patients (59% lung cancer and gallbladder surgery) would choose another surgeon at the same hospital if that would permit surgery within 4 workdays. Patients may value discussing change in surgeon because they have little prior surgical experience. We considered every patient in the State of Iowa having outpatient surgery at a hospital during 3 months. Most patients (64.3%) had no subsequent outpatient or inpatient surgery at any hospital statewide for at least 2 years.

## 2 - Adaptive Capacity Planning for Ambulatory Surgery Centers

Seokjun Youn, Texas A&M University, 320M Wehner Building, 4217 Texas A&M University, College Station, TX, 77840-4217, United States, Harry Neil Geismar, Chelliah Sriskandarajah, Vikram Tiwari

Capacity planning for Ambulatory Surgery Centers (ASCs) is challenging due to multi-stage nature of services and significant uncertainty in patient-mix as well as service duration. We propose a bed capacity planning framework for ASCs and provide implications for practitioners, for example, the impacts of changes in patient-mix or ASC operating structures on capacity.

## 3 - Evaluating Appointment Scheduling Policies at the Division of Colon and Rectal Surgery of Mayo Clinic

Narges Shahraki, Mayo Clinic, Rochester, MN, United States, Mustafa Y. Sir, David Larson, Brian Bernard, Todd Huschka, Gabriela Martinez, Curtis Storlie, Kalyan Pasupathy

In this study, we develop a novel multi-level model to evaluate the impact of a priority-based scheduling policy implemented at the Division of Colon and Rectal Surgery of Mayo Clinic. Access time to surgery and variability on the surgeon end-of-day are considered as the performance metrics in our comparison. The results show that the priority-based policy is an effective scheduling policy since it distributes the demand properly through the planning horizon and helps the system to service the high priority patients more efficiently.

## 4 - Integrated Routing and Scheduling of Anesthesiologists to Off-locations

Joonyup Eun, Vanderbilt University Medical Center, Nashville, TN, United States, Vikram Tiwari, Mitchell H. Tsai, Max Breidenstein, Warren S. Sandberg

We develop a scenario-based stochastic optimization model that factors in distances between off-location sites, idle time, and tardiness of cases to determine anesthesiologists' assignment. Most solutions reduce the number of required anesthesia providers than scheduled in real situations. By changing the relative weights, we evaluate the trade-offs among the four performance measures.

## ■ SD60

West Bldg 102B

**Capacity Management in Healthcare**

Sponsored: Health Applications

Sponsored Session

Chair: Nan Liu, Boston College, Chestnut Hill, MA, 02467, United States

Co-Chair: Pengyi Shi, Purdue University, West Lafayette, IN, 47907, United States

**1 - Flexible FDA Approval Policies**

Taylor Corcoran, UCLA Anderson School of Management, 110 Westwood Plaza, Los Angeles, CA, 90024, United States, Fernanda Bravo, Elisa Long

The FDA requires clinical trial evidence that is statistically significant at the 2.5% level when approving novel drugs, but the agency often uses regulatory discretion when interpreting these standards. Factors such as target disease severity, prevalence, and availability of existing therapies are qualitatively considered, yet no quantitative framework is used to evaluate how such characteristics impact approval standards. We propose a novel queueing network model to analyze the drug approval process, which explicitly incorporates these factors, as well as obsolescence among drugs.

**2 - Coordinated Clinic Surgery Appointment Scheduling: A Multi-stage Stochastic and Distributionally Robust Approach**

Esmaeil Keyvanshokoo, University of Michigan-Ann Arbor, Ann Arbor, MI, 48108-1020, United States, Pooyan Kazemian, Mark P. Van Oyen

Providing timely access to surgery/clinic is crucial for patients with high acuity diseases like cancer. In this paper, we present an integrated multi-stage stochastic and distributionally robust optimization approach for coordinating both clinic and surgery appointments to meet access delay service levels. The methodology is applied to historical hospital data to benchmark its better performance.

**3 - An Empirical Investigation on Overflow Decisions in Inpatient Flow and Their Impact on Patient Outcomes**

Jing Dong, Columbia University, Uris Hall 413, 3022 Broadway, New York, NY, 60208, United States, Pengyi Shi, Fanyin Zheng

Using patient level data from a large teaching hospital in Singapore, we study the overflow decision in inpatient flow management and its impact on both individual-level patient outcomes and system-level congestion. We first empirically investigate the causal effect of overflow on inpatient length-of-stay (LOS). Then, we develop a structural model to estimate what factors drive the overflow decision in practice. Finally, motivated by the empirical findings, we use simulations to identify optimal overflow decisions that balance the cost and benefit of overflow.

**4 - Balancing the Scale: Readmission Risk at Discharge vs Inpatient Unit Congestion**

Pengyi Shi, Purdue University, 403 W. State St, Krannert School of Management, Kran 472, West Lafayette, IN, 47907, United States, Jonathan Helm, Jivan Romain Deglise-Hawkinson, Julian Pan

Early discharging patients at high inpatient occupancy mitigates the impact of ward overcrowding, but early discharged patients may experience increased readmission risk and other adverse outcomes. In this work, we develop a practical decision support tool to aid hospitals balance between individual discharge risk and ward congestion. We start from building a prediction model that updates the readmission risk over a patient's stay in the hospital. We then integrate this prediction model into a discharge optimization framework and develop a series of methods to overcome the curse of dimensionality. Lastly, we discuss the ongoing implementation efforts of this discharge optimization tool.

## ■ SD61

West Bldg 102C

**Recent Frontiers on Energy Markets**

Emerging Topic: Energy and Climate

Emerging Topic Session

Chair: Feng Qiu, Argonne National Laboratory, Lemont, IL, 60439, United States

**1 - Computational Challenges to ISO Markets and Planning**

Richard Paul O'Neill, Federal Energy Regulatory Commission, Silver Spring, MD, United States

This presentation will look at the computational challenges in the ISO markets and planning transmission. In ISO markets there is needed for good solutions in a specific time period. Problems can be characterized as MIPs and non-linear optimizations. In ISO markets, the transmission expansion problem is much more

difficult than for vertical integrated utilities and IRPs. Transmission expansion depends on assumptions concerning the future type and location of generation and load. Presentation will address newer models for transmission expansion and cost allocation that could improve the process.

**2 - Ongoing Challenges on Wholesale Electricity Market Clearing**

Yonghong Chen, Midwest ISO, 720 City Center Drive, Carmel, IN, 46032, United States

This presentation introduces on-going challenges faced by wholesale electricity market and the R&D efforts to overcome these challenges, especially in the area of improving computational capabilities to incorporate future resources such as storages, distributed energy resources, virtual power plants, etc.

**3 - Challenges in Integrating Variable Energy Resources in RTO Markets**

Khai Le, PCI, Norman, OK, United States

This presentation explores the key operating challenges that RTOS are currently facing as more variable energy resources (VERs) are added to their generation mix: ? What are the potential impacts of adding wind & solar resources on system operations and system reliability? ? As more VERs are added, do you have to increase your regulating-reserve requirements to maintain NERC CPS1 and CPS2 requirements? ? What are the potential increases in ancillary-service costs for integrating VERs?

**4 - Challenges in Integrating Solar Resources in Large Balancing Areas**

Mark Oliver, Duke Energy

This presentation provides an overview of challenges faced by non-RTO/ISO utilities in meeting NERC balancing requirements while accommodating rapid growth of PURPA solar energy, including forecasting and monitoring of distributed solar energy, investments to improve operational flexibility of the conventional generation fleet, and implications of third party energy "solar plus storage" resources.

**5 - Polynomial Time Algorithms and Extended Formulations for Unit Commitment Problems**

Yongpei Guan, University of Florida, 303 Weil Hall, P.O. Box 116595, Gainesville, FL, 32611, United States, Kai Pan, Kezhou Zhou

Unit commitment is fundamental and embedded in the models at different stages of power system operations. In this talk, we present polynomial-time algorithms for the unit commitment problems with a general convex cost function and piecewise linear cost function, respectively. We also report the corresponding extended formulation and further study on its stochastic counterpart.

## ■ SD62

West Bldg 103A

**Joint Session DM/Practice Curated: Data Science in Social Media & Societal Issues**

Sponsored: Data Mining

Sponsored Session

Chair: Mohammad Abdollahi, Wayne State University, 4815 Fourth Street, Room 1067, Detroit, MI, 48202, United States

**1 - Annual Report Readability, Timeliness, and Earnings**

Yuan Song, Tongji University, Room 1413, Tongji Building A, Siping Rd 1500, Shanghai, 200092, China, Shouyi Wang, Hongwei Wang

This paper studies the associations between earnings and annual report readability and timeliness based on China's capital market. Empirical results indicate that firms with higher earnings are likely to disclose their annual reports earlier in a timely manner and smaller document size; the annual reports of firms with lower earnings are later disclosed and harder to read in a larger file size. The results are consistent with both firms reporting a loss and firms with positive earnings. Additionally, among China's multi-tier capital market system, the annual report readability and timeliness in SHSE are more powerful to explain earnings than in SZMB and SME.

**2 - Rethinking Resilience Analytics for Cyber-physical-social Systems**

David L. Alderson, Naval Postgraduate School, 1411 Cunningham Road, Monterey, CA, 93943, United States, Daniel Eisenberg, Thomas P. Seager

The concept of 'resilience analytics' has been proposed to leverage the promise of big data and associated analytic techniques to improve the resilience of interdependent critical infrastructure systems and the communities supported by them. Given the prevalence of high-profile disasters and advances in data-driven analytic techniques, the temptation to develop resilience analytics without question is almost overwhelming. However, without critical examination of the assumptions and limitations of existing analytics, such efforts may ironically create more brittle cyber-physical-social (CPS) systems from overconfidence, myopia, and/or loss of adaptive or innovative capacity.



### 3 - A Deep Learning Approach for Travel Time Prediction

Mohammad Abdollahi, Wayne State University, 4815 Fourth Street, Room 1067, Detroit, MI, 48202, United States, Kai Yang

Travel time is a fundamental measure in transportation which its accurate prediction is also crucial to the development of intelligent transportation systems. In this paper, we study travel time prediction for New York cabs using deep learning. First, we extract features (by clustering and other techniques) and combine different datasets such as weather and fastest routes. Then, a deep stacked autoencoder for feature representation is presented. These feature transformation makes the feature space more robust and less prone to overfitting. Finally, we compare the effect of feature extraction on performance of different regressors such as boosted trees, deep belief networks, and etc.

### ■ SD63

West Bldg 103B

### Joint Session DM/AI: Data-driven Decision Modeling for Healthcare

Sponsored: Data Mining

Sponsored Session

Chair: Tong Wang, University of Iowa, Iowa City, IA, United States

#### 1 - Feature-efficient Multi-value Rule Sets for Interpretable Patient Mortality Prediction

Tong Wang, University of Iowa, Pappajohn Business Build, 21 East Market Street, Iowa City, IA, 52245, United States, Allareddy Veerajalandhar, Sankeerth Rampa, Veerasathpurush Allareddy

We propose Multi-vAlue Rule Set (MARS) for predicting patient mortality. Compared to rule sets built from single-valued rules, MARS introduces a more generalized form of association rules that allows multiple values in a condition. Rules of this form are more concise than classical single-valued rules in capturing and describing patterns in data. Our formulation also pursues a higher efficiency of feature utilization, which reduces possible cost in data collection and storage. We applied MARS model on a dataset from Nationwide Inpatient Sample and our model achieved better performance than baseline interpretable models and the patient risk classification system currently used by hospitals.

#### 2 - Optimizing Patient Outcomes via Inverse Classification

Michael Lash, University of Iowa, 2 West Washington Street, B4 MacLean Hall, Iowa City, IA, 52242, United States

Inverse classification, the process of optimizing the decision features of a test instance using a classifier-based oracle, is a powerful technology that produces personalized, outcome-optimized recommendations. In our formulation, these recommendations are produced by taking into account patient-specific preferences regarding feature priority and cumulative effort. Subsequently, a result is produced showing the improvement in outcome probability and the changes the instance must make to achieve such an improvement. In this talk I present this formulation, along with our corresponding set of methodology, and discuss its application to patient decision making.

#### 3 - Flame – A Fast Large Almost Exact Matching Algorithm for Causal Inference

Cynthia Rudin, LSRC / Box 90129, Durham, NC, 27708, United States

The FLAME algorithm (Fast Large Almost Matching Exactly) is a large scale matching technique for causal inference. It can handle data so large that it cannot fit in memory, and creates high-quality matches. I will discuss this algorithm and related methods.

#### 4 - Limits of Interpretable Machine Learning in Healthcare

Muhammad Aurangzeb Ahmad, University of Washington, Tacoma, WA, United States

While interpretability of machine learning systems is critical in holding such systems accountable, practical constraints limit the use of interpretable systems: Comparison of explanations across interpretable machine learning systems, theoretical guarantees of mimic models, soundness vs. completeness of explanations against cognitive limitations, comparison of risk across multiple factors for interpretable models etc. Addressing these limitations will allow us to build better interpretable machine learning systems in healthcare.

### ■ SD64

West Bldg 104A

### Joint Session DM/Practice Curated: Data Science and Analytics in Healthcare II

Sponsored: Data Mining

Sponsored Session

Chair: Dung Hai Nguyen, Mercy Health, 655 Maryville Center Drive, Saint Louis, MO, 63141, United States

#### 1 - Advances in Density-based Gaze Fixation Identification: Optimization for Outlier Sensitivity, and Automated Detection of Density-modulation Parameter

Wen Liu, Worcester Polytechnic Institute, Worcester, MA, United States, Andrew C. Trapp, Soussan Djamabasi

Eye tracking is an increasingly common technology with applications to healthcare. Of great interest in eye-tracking studies are fixations, indicative of attention and awareness. However, eye-tracker imprecision can lead to outlier points, e.g. blinks or other anomalies. We extend our density-based fixation identification optimization formulations to account for outlier sensitivity. As our formulations are parameterized by a key density-modulation parameter, we also discuss machine learning approaches for its automatic detection. We conclude with encouraging computational results.

#### 2 - A Continuous Time Bayesian Network Model for Identifying Patterns of Multiple Chronic Conditions

Syed Hasib Akhter Faruqi, Graduate Research Assistant, University of Texas-San Antonio, San Antonio, TX, 78256, United States, Adel Alaeddini, Carlos A. Jaramillo, Mary Jo Pugh

Emergence of multiple chronic conditions (MCC) adds complexity in managing patient healthcare design, care, and cost. Hence, it is required to have an effective management of MCC that uses real-time decision making in a big data setting. The proposed study uses de-identified data from a large national cohort of patients (N = 608,503) who entered care in the Department of Veterans Affairs, to identify the risk factors that affect the evolution of MCC. A Continuous Time Bayesian Network is used to examine the interactions of patient disease states and identify major dependencies among MCC that can be used to predict the onset of emerging conditions according to patient level risk factors.

### ■ SD65

West Bldg 104B

### Joint Session DM/Practice Curated: Big Data, Text Mining, and E-commerce

Sponsored: Data Mining

Sponsored Session

Chair: Amarpreet Kohli, University of Southern Maine, P.O. B, Portland, ME, 04104, United States

#### 1 - Dynamic Seed Identification and Activation for Influence Maximization

Yerasani Sinjana, Research Scholar, Indian Institute of Technology Kharagpur, Kharagpur, 721302, India, Monalisa Sarma, Manoj Kumar Tiwari

In this paper, we consider a network where a set of nodes are termed as seed nodes at each time interval in scheduling seed activation. Seeds are tactically activated for maximizing the spread of influence on social networks: Given a time period for activation, campaign budget, and a network where a set of nodes can be selected as seeds to propagate information. At each stage, time-dependent partial activation of nodes information is used to track the opinions and awareness of users. Activating different users at different periods of time can be termed as Dynamic Seed Activation Problem and can be rewritten as mixed integer programming. A memetic algorithm is employed for scheduling seed activation.

## 2 - Putting Prediction into Practice: The Case of Restaurant Hygiene Inspections

Michael Luca, Harvard Business School, Boston, MA,  
United States, Edward Glaeser, Andrew Hillis, Hyunjin Kim

Partnering with Yelp and the City of Boston, we run an experiment comparing an inspector-curated list of restaurants to inspect (i.e. business-as-usual) to algorithm-created lists based on predictions of which restaurants are most likely to have health code violations. We find that even simple algorithms outperform business-as-usual, identifying 50% more violations per inspection. However, one practical barrier to implementing algorithms is compliance - inspectors were less likely to comply with a directive to inspect a restaurant based on the algorithm. The algorithm also has fairness implications. For example, the algorithm-based predictions were more likely to target ethnic restaurants.

## 3 - Text Analysis for Educational Crowdfunding Success: Comparison between Different Textual Components

Mingyan Xu, Baruch College, New York, NY, 10075, United States

Educational crowdfunding is emerging as a salient hit on online platforms. Despite its growing popularity, the antecedents of funding success are far from certain. To help the fundraisers (i.e. teachers) better understand factors affecting funding success and improve their success rate, this study provides an empirical analysis on one large U.S. educational crowdfunding platform. Specifically, it analyzes the impact of the textual features from different components of the project description on funding success and identifies the differences of the impact on different levels of the project economic needs. The implications of the findings for fundraisers have also been discussed.

## 4 - How User-generated Content Predict Box-office Sales for Different Movie Genres

Pei-Hua Chen, National Chiao Tung University, Hsin-Chu, 300, Taiwan, Chia-Tze Chang

This study explored the factors that affect two kinds of movie-goers: innovators and imitators. For innovators, we included casts of the movies and various movie attributes to predict box-office sales on opening weekends. In addition to the variables used for innovators, we added user-generated contents to predict sales increase for imitators. We analyzed the effects of movie-goer emotions and experiences on box-office sales for different movie genres. The results showed that different movie genres provide different experiences and emotions for movie-goers.

## 5 - Using Text Mining to Analyze Consumer Brands Sentiments of Smart Watches

Amarpreet Kohli, Associate Professor, University of Southern Maine, P.O.Box 9300, Portland, ME, 04104, United States, Solomon Nkhalamba, Zhenning Xu

Social media has been a significant part of many businesses and organizations. Many firms are utilizing social media platforms to interact with their customers and clients to gauge value of their products and services through diverse stakeholders. The advent of social media platforms such as Twitter and Facebook have provided companies with easier access to collect customer opinions or reviews than the traditional survey methods and focus group approaches. To demonstrate the great potential of social media in unlocking the useful knowledge of market products, this paper uses text mining to analyze consumers' twitter sentiments of smart watches.

## SD66

West Bldg 105A

### Joint Session AI/Practice Curated: Health Analytics with Online Data

Sponsored: Artificial Intelligence

Sponsored Session

Chair: Kang Zhao, University of Iowa, Iowa City, IA, 52242, United States

## 1 - The Effects of Online Social Interactions on the Emotions of Depression Patients

Qingpeng Zhang, City University of Hong Kong, 83 Tat Chee Avenue, 6/F, Academic 1, Kowloon, 12180, Hong Kong, Jiaqi Zhou, Xin Li

Social media-based online health communities (OHCs) present a new platform for patients to seek social support, particularly for depressive patients. In this talk, we will introduce our research on characterizing the effect of social interactions in OHCs. We collected the full data of a major Chinese OHC. Quantitative analyses revealed that the social interactions with other patients in OHCs could positively influence the emotion of patients with depression.

## 2 - Mining User-generated Content in an Online Smoking Cessation Community to Identify Smoking Status: A Machine Learning Approach

Kang Zhao, University of Iowa, S224 PBB, Iowa City, IA, 52242, United States, Xi Wang, Amanda Graham, Sarah Cha, Michael Amato, George Papandonatos, Amy Cohn, Jennifer Pearson

Online smoking cessation communities attract hundreds of thousands of smokers each year. Content shared by users in such communities may contain important information that could enable more effective and personally tailored cessation treatment recommendations. This study demonstrates a novel approach to identify individual users' smoking status by applying machine learning techniques to user-generated content in online cessation communities. Evaluate by data from a popular online community for smokers in U.S., our approach can improve the performance of cessation identification by 9.7%.

## 3 - The Impact of Doctors Joining in Expert Groups on Individual Performance in Online Health Communities

Wanxin Qiao, Beijing Institute of Technology, No.5,Zhongguancun Street, Haidian District, Beijing, 100081, China, Lini Kuang, Zhijun Yan, Tianmei Wang, Baowen Sun

Despite a growing literature on the impacts of person-group fit on group performance, there is little evidence on how the person-group fit affects individual performance. Using a unique panel dataset, we explore the impact of doctor-expert group fit on doctor's performance, and how the effects differ among doctors with different professional titles. Our results show that doctor joining in groups has positively affect individual performance, and doctors with low titles have positive impact on individual performance. Our work contributes to provide a deeper understanding of the relationship between doctors and expert groups in online health community.

## 4 - AI Enhanced Innovations for Large National Healthcare Survey Data Analytics

Steven B. Cohen, RTI International, 701 13th Street NW, Washington, DC, 20005-3967, United States

This presentation focuses on the development and implementation of AI and machine learning enhanced applications to imputation for national health and health care survey efforts that achieve efficiencies in terms of cost and time while satisfying well defined levels of accuracy that ensure data integrity. Attention is given to enhanced processes that serve as an alternative solution to manual, repetitive or time-intensive tasks; operationalize decisions based upon predefined outcome preferences and upon access to input data that sufficiently informs the decisions; and facilitate real-time interpretation and interactions for accessing and acting upon the AI-derived decisions.

## SD67

West Bldg 105B

### Joint Session ISS/Practice Curated: AI and Smart Technologies

Sponsored: Information Systems

Sponsored Session

Chair: Xinxin Li, University of Connecticut, University of Connecticut, Storrs, CT, 06269, United States

## 1 - Reinforcement Mechanism Design, with Applications to Dynamic Pricing in Sponsored Search Auctions

Michael Zhang, Professor, Chinese University of Hong Kong, Decision Sciences and Managerial Economics, 9th Floor, CYT Building, Shatin, N.T., Hong Kong, Weiran Shen, Binghui Peng, Hanpeng Liu, Ruohan Qian, Yan Hong, Zhi Guo, Zongyao Ding, Pengjun Lu, Pingzhong Tang

We apply reinforcement learning techniques and propose what we call reinforcement mechanism design to tackle the dynamic pricing problem in sponsored search auctions. In contrast to previous works that rely on rationality and common knowledge among the bidders, we take a data-driven approach. We implement our proposed technique at a major search engine: We first train a buyer behavior model with a real bidding data set. We then put forward a reinforcement/MDP (Markov Decision Process)-based algorithm that optimizes reserve prices over time, in a GSP-like auction. Experiments demonstrate that our framework outperforms several strategies currently in use.

## 2 - The Dynamic Impact of Quantity Restriction on Backers' Investment Intention

Zhijin Zhou, University of Washington, Foster School of Business, Seattle, WA, 98195, United States, Chaoliang Ma, Yong Tan

We analyze the effect of implementing quantity restriction, a prevalent marketing strategy to promote sales in the off-line market, in the context of crowdfunding. Using a dynamic panel dataset, we start with a preliminary analysis to get insights into backers' basic response patterns. Then, we extend our model and allow for (a) varying parameters to fully capture the underlying dynamics, (b) correlation in the errors that might affect parameter evolving process. Our results suggest that the scarcity of a product increases backers' overall evaluation of the product, while it plays a moderating role in attenuating backers' reliance on peers' action and decreasing their price sensitivity.

## 3 - A Model of Smart Technologies

Xinxin Li, University of Connecticut, 2100 Hillside Road U-1041, Storrs, CT, 06269, United States, Yuxin Chen, Monica Sun

We study the optimal pricing and design of smart technologies that are based on artificial intelligence (AI) and can learn consumers' preferences over time. Our preliminary analysis suggests that it is not always profitable to increase the smartness of a firm's technology even when doing so does not involve direct costs. The "price" in our model can be interpreted as either a direct price that consumers have to pay to the firm or a form of advertising exposure. Correspondingly, our model has implications not only for the pricing and design of smart technologies and their interaction with consumers, but also for platforms on which advertisers aim to target the users of smart technologies.

## 4 - Too Much of a Good Thing?

Wei Zhou, PhD Student, University of Arizona, Tucson, AZ, 85721, United States, Mingfeng Lin

The importance of reputation online is well established and is especially true for service-oriented markets spanning such as professional services. We explore limits to such claims using a detailed transactional dataset and discuss implications for designing such reputation systems.

## SD68

West Bldg 105C

## IISE Transactions Invited Session

Sponsored: Quality, Statistics and Reliability

Sponsored Session

Chair: Yu Ding, Texas A&M University, ETB 4016, MS 3131, Texas A&M University, College Station, TX, 77843-3131, United States

## 1 - Causation-based Process Monitoring and Diagnosis for Multivariate Categorical Processes

Jian Li, School of Management, Xi'an Jiaotong University, No 28 Xianning West Road, Xi'an, China

Many applications involve causal relationships among multiple categorical variables/factors, where shifts at cause factors will propagate to their effect factors. A causation-based rather than correlation-based description would better account for such causal relationships. We integrate a Bayesian network and construct one general and one directional control charts for detecting shifts in the conditional probabilities of categorical factors. Simulations have demonstrated their effectiveness.

## 2 - Ensemble Bayesian SPC: Multi-Mode Process Monitoring for Novelty Detection

Irad Ben-Gal, Tel Aviv University, Tel-Aviv, Israel, Marcelo Bacher.

We propose a monitoring method based on a Bayesian analysis of an ensemble-of-classifiers for Statistical Process Control (SPC) of multi-mode systems. A specific case is considered, in which new modes of operations (new classes), also called "novelties," are identified during the monitoring stage of the system. The proposed Ensemble-Bayesian SPC (EB-SPC) models the known operating modes by categorizing their corresponding observations into data classes that are detected during the training stage. Ensembles of decision trees are trained over replicated subspaces of features, with class-dependent thresholds being computed and used to detect novelties. In contrast with existing monitoring approaches that often focus on a single operating mode as the "in-control" class, the EB-SPC exploits the joint information of the trained classes and combines the posterior probabilities of various classifiers by using a "mixture-of-experts" approach. Performance evaluation on real datasets from both public repositories and real-world semiconductor datasets shows that the EB-SPC outperforms both conventional multivariate SPC as well as ensemble-of-classifiers methods and has a high potential for novelty detection including the monitoring of multimode systems.

## 3 - Discussant

Matthew Plumlee, Northwestern University, IL, United States

This talk will discuss the two other papers in this session, discussing achievements, potential drawbacks, connections to other literature, and possible extensions.

## SD69

West Bldg 106A

## Functional Data or Profiled Response Analysis

Sponsored: Quality, Statistics and Reliability

Sponsored Session

Chair: Rong Pan, Arizona State University, Tempe, AZ, 85287-8809, United States

## 1 - An Efficient Surrogate Model for Emulation and Physics Extraction of Large Eddy Simulations

Chih-Li Sung, PhD, Georgia Institute of Technology, Atlanta, GA, United States, Simon Mak, Xingjian Wang, Shiang-Ting Yeh, Yu-Hung Chang, Roshan J. Vengazhiyil, Vigor Yang, C. F. Jeff Wu

In the quest for advanced propulsion and power-generation systems, high-fidelity simulations are too computationally expensive to survey the desired design space. In this paper, we propose a new surrogate model that provides efficient prediction and uncertainty quantification of turbulent flows in swirl injectors with varying geometries. The novelty of the proposed method lies in the incorporation of known physical properties of the fluid flow as simplifying assumptions for the statistical model. In view of the massive simulation data at hand, which is on the order of hundreds of gigabytes, these assumptions allow for accurate flow predictions in around an hour of computation time.

## 2 - Dynamic Curve Alignment Based on Penalized-spline Smoothing

Kaibo Wang, Professor, Tsinghua University, Department of Industrial Engineering, Tsinghua University, Beijing, 100084, China

Unaligned profiles with amplitude and phase variabilities have to be registered (aligned) through shifting, time warping or coordinate alignment so that samples are comparable and easy to handle. This work proposes a penalized-spline smoothing method for profile alignment. The strategy is to capture the smoothness and spatially correlated features of warping shifts through a penalized registration function. A dynamic programming algorithm is developed to obtain the optimal path.

## 3 - Nearest-neighbor Gaussian Process Emulation for Tensor Responses in Freeze Nano Printing

Hongyue Sun, University at Buffalo, 319 Bell Hall, Industrial and Systems Engineering, Buffalo, NY, 14260, United States, Guanglei Zhao, Chi Zhou

Existing energy storage devices have either high power density or high energy density, but not both. Freeze nano printing can potentially solve the problem by combining inkjet printing and freeze casting to print multi-scale porous structures. In this process, the thermal history is fundamental to its quality and productivity. The thermal history evolves over space and time, and cannot be fully captured by existing sensors. The physical simulation models can describe the spatial-temporal thermal history (i.e., tensor response) but are computationally demanding. We propose a Nearest-Neighbor Gaussian Process (NNGP) based emulator to address the computation problem for the tensor response.

## 4 - Experimental Designs for Studying Dynamic Response Modeled by B-splines

Rong Pan, Arizona State University, School of Computing Informatics & Decision Sys, P.O. Box 878809, Tempe, AZ, 85287-8809, United States

In this talk we discuss the B-spline models used for modeling dynamic responses from industrial experiments and how to design the experiment to collect system responses more efficiently.

## SD70

West Bldg 106B

## Joint Session QSR/DM: Machine Learning Based Approaches for Semiconductor Manufacturing Processes

Sponsored: Quality, Statistics and Reliability

Sponsored Session

Chair: Youngseon Jeong, Chonnam National University, 5012 King David Boulevard, Annandale, VA, 22003-4033, United States

Co-Chair: Jeongsub Choi, Rutgers-State University of New Jersey, Highland Park, NJ, 08904, United States



### 1 - Intrinsic Decomposition of Acoustic Emission and Nonparametric State Machine Model for Real-time Monitoring of Precision Micro-machining Process

Zimo Wang, Texas A&M University, Industrial & System Engineering Dept, college station, TX, 77843, United States, Satish Bukkapatnam

We present an approach using intrinsic time-scale decomposition and Dirichlet processes Gaussian state machine to analyze the transient behaviors of Acoustic Emission signals. Experimental studies showed that the presented approach could timely detect changes when the precision micro-machining process undergoes variations on material structures and/or fundamental cutting mechanisms.

### 2 - Defect Classification using Ensemble Convolutional Neural Network in Semiconductor Manufacturing

Hyung-Seok Kang, Samsung Electronics, Hwaseong-si, Gyeonggi-do, Korea, Republic of, Jaewoong Shim, Kim Kil Soo, Seung Hoon Tong

In semiconductor manufacturing, visual inspection is a fundamental process for defect detection and classification. In the case of 3D-Stacked DRAM with VIA (vertical interconnect access) technology, electrical inspection can be performed after assembly, so that defects in the VIA process can be detected only by appearance. The inspection equipment shoots multiple images at different angles with high and low magnification for failure analysis. In this study, we apply the ensemble Convolutional Neural Network (CNN) which utilizes multiple images in combination, and also conduct experiments on open set recognition that recognizes untrained types considering the actual environments.

### 3 - Prioritize Interaction Effects on Wafer Defects for Multistage Semiconductor Fabrication Based on Applied Association Rule Mining

Jinsik Kim, Samsung Electronics, Hwaseong, Gyeonggi-do, Korea, Republic of, Jaewoong Shim, Chanhwi Jung, Doh Soon Kwak, Kunhan Kim, Seung Hoon Tong

The methodology of finding the single cause of defects in semiconductor manufacturing has been studied a lot. However, as the product matures, the single causes are largely resolved and necessity of the search for the interaction of two factors emerges. The number of combinations of two or more factors in a complex manufacturing process is enormous, so it is impossible to inspect all cases. We propose a methodology to identify interaction of factors that leads to Wafer Defects using association rule mining algorithm. In addition, we validate this methodology by applying it on real-world data.

### 4 - A Scale-invariant Method for Quality Inspection of Objects Created by Additive Manufacturing

Yu Jin, Ph.D Student, University of Arkansas, 4207 Bell Engineering Center, Fayetteville, AR, 72701, United States, Haitao Liao

Additive Manufacturing (AM) has shown great advantages in producing objects with complex geometric features. In broader applications, the functionality of printed parts is significantly affected by not only the quality but also the relative positioning of key features. In this research, a new scale-invariant quality profile is established based on the point clouds of printed parts obtained from a laser scanner. The new quality inspection method is able to quantify the fabrication non-conformity of individual features and the key features' relative positioning. Numerical examples are provided to demonstrate the effectiveness and efficiency of the proposed quality inspection method.

## SD71

West Bldg 106C

### Joint Session ICS/Practice Curated: Advances in Computational Stochastic Optimization and Applications

Sponsored: Computing

Sponsored Session

Chair: Harsha Gangammanavar, Southern Methodist University, Dallas, TX, 75275, United States

#### 1 - Monte Carlo Tree Search with Sampled Information Relaxation Dual Bounds

Lina Al-Kanj, Princeton University, Olden Street, Sherrerd Hall, Office 115, Princeton, NJ, 08542, United States, Daniel Jiang, Warren B. Powell

MCTS is a well-known strategy for solving sequential decision problems, particularly in the area of game-play AI. We propose a new technique called Primal-Dual MCTS that utilizes sampled information relaxation (Brown et al., 2010) bounds on potential actions in order to make tree expansion decisions. The approach shows promise when used to optimize the behavior of a driver navigating a graph while operating on a ride-sharing platform.

#### 2 - Variable Sample-size Stochastic Approximation Scheme for Two-stage Stochastic Economic Dispatch

Wendian Wan, Pennsylvania State University, 351 Leonhard Building, University Park, PA, 16802, United States, Uday Shanbhag, Mort David Webster

This talk introduces the development of variable sample-size stochastic approximation schemes for two-stage stochastic convex programs. Our focus lies in applying this class of schemes towards the solution of a broad class of adaptive stochastic decision-making problems arising in the operation of large-scale power systems. In this talk, we consider the stochastic economic dispatch problem. In such problems, a first-stage dispatch is made contingent on taking a recourse decision when the uncertainty reveals itself. Preliminary numerics reveal that the proposed schemes provide accurate solutions but require far less time than traditional approaches like standard stochastic approximation.

#### 3 - Stochastic Decomposition for Two-stage Stochastic Linear Programs with Random Cost Coefficients

Harsha Gangammanavar, Southern Methodist University, Department of EMIS, P.O. Box 750123, Dallas, TX, 75275, United States, Yifan Liu, Suvrajeet Sen

The Stochastic Decomposition (SD) algorithm has been a computationally proficient tool to tackle real-scale stochastic optimization problems arising in practical applications. In this talk we present new enhancements to this sequential sampling-based algorithm to address two-stage stochastic linear programs with random cost coefficients. We demonstrate their performance through results from our computational experiments.

#### 4 - Simulation-based Hybrid Stochastic Approximation using Common Random Numbers

Marie Chau, Virginia Commonwealth University, 1015 Floyd Avenue, Richmond, VA, 23220, United States, Jong J. Lee, Michael Fu

Common Random Numbers (CRN) is a variance reduction method, which can be used to increase the typical  $O(n^{-1/3})$  convergence rate of gradient-free stochastic approximation (SA) to match the optimal  $O(n^{-1/2})$  convergence rate of gradient-based SA. Secant-Tangents AveRaged (STAR) and adaptive Secant-Tangents AveRaged (aSTAR) simultaneous perturbation SA are hybrid methods, which combine gradient-free and gradient-based SA algorithms. By applying CRN assumptions, STAR and aSTAR can achieve the optimal asymptotic convergence rate under milder conditions.

## SD72

West Bldg 211A

### Decision Process: Practical and Methodological Issues in MCDM/A

Sponsored: Multiple Criteria Decision Making

Sponsored Session

Chair: Adiel Teixeira De Almeida, Universidade Federal de Pernambuco, Recife PE, 50630-970, Brazil

Co-Chair: Danielle Costa Morais, Universidade Federal de Pernambuco, Recife - PE, 52020-212, Brazil

#### 1 - Preference Elicitation for Multicriteria Group Decision Making using FITradeoff

Adiel Teixeira De Almeida, Universidade Federal de Pernambuco, Cx Postal 7462, Recife PE, 50630-970, Brazil, Eduarda Asfora Frej

Preference elicitation of Decision Makers (DMs) is one of the most relevant tasks in multicriteria group decision making (MCGDM). The facilitation process uses knowledge in the intersection of several topics, such as: analytical models, cognitive process of DMs and the organizational and social interaction of a DMs' group. In this work the decision process considers a framework for building multicriteria decision models. FITradeoff (Flexible and Interactive Tradeoff) method is used for preference elicitation in this MCGDM process, with criteria aggregation by an additive model in MAVT scope, using partial information. A decision support system, available at [www.fitradeoff.org](http://www.fitradeoff.org), is applied.

#### 2 - Group Decision Model for Logistics Problem using Ordered Weighted Distance

José Leao Silva-Filho, Master, Universidade Federal de Pernambuco, Recife, Brazil, Danielle Morais

In corporative scenario, logistics is characterized by extreme competition, requiring efficiency in its processes. Decisions in this field can be complex depending on their strategic level and the number of Decision-Makers involved. This study proposes a group decision model for strategic logistics problem, using ordered weighted vectors. A numerical simulation of a real company relocation is presented to illustrate the applicability of the model.

### 3 - Multicriteria Model for Public Security Planning

Caroline Miranda Mota, Associate Professor, Universidade Federal de Pernambuco, Rua General Salgado 180 Apartment 201, Boa Viagem Recife PE, Recife, 51130320, Brazil, Ciro Figueiredo, Debora Pereira

Public security planning involves the effective use of resources to deal with crime prevention and reduction. Countries all over the world have made many efforts to reduce crime rates, although this phenomenon is more critical in developing nations. This study is concerned with an effective resource allocation in the context of public policies to prevent crime occurrence. It involves the application of combined methodologies to explore the influence of crime risk factors and to prioritize places that deserve more resources. We considered social, economic, and demographic variables to analyze critical zones, using GIS and multi-criteria approach.

### 4 - Multicriteria Model to Support Maintenance Planning of Infrastructure Devices

Cristiano Cavalcante, Associate Professor, Universidade Federal de Pernambuco, Av. da Arquitetura, s/n, Centro de Tecnologia e Geociências (CTG), Prédio do Departamento de Engenharia de Produção, Sala 201 A, Cidade Universitária, Recife - Pernambuco, 50740-550, Brazil, Alexandre R. Alberti

The objective of this work is to present contributions to the definition of maintenance policies for protection devices in infrastructure systems. A hybrid inspection and preventive replacement policy is described by a mathematical model that incorporates important aspects of maintenance quality. The model enables to measure the consequences of unmet demands of protection devices as a resilience factor. An approach based on the application of Multiattribute Utility Theory is proposed to find the best compromise relationship between these two criteria in order to define maintenance policies aligned with the decision-maker's preferences.

## ■ SD73

West Bldg 211B

### JFIG Panel Discussion: Work-Life Balance

Sponsored: Junior Faculty JFIG

Sponsored Session

Chair: Ehsan Salari, Wichita State University, Wichita, KS, 67260, United States

Co-Chair: Canan Gunes Corlu, Boston University, Boston University, Boston, MA, 02215, United States

#### 1 - JFIG Panel Discussion: Work-Life Balance

Ehsan Salari, Wichita State University, 120C Engineering Building, 1845 Fairmount St., Wichita, KS, 67260, United States

Panelists will share lessons learned, challenges, and best practices in balancing job responsibilities in academia with responsibilities outside of work.

#### Panelists

Jennifer K. Ryan, University of Nebraska-Lincoln, Dept of Supply Chain Management & Analytics, College of Business Administration, Lincoln, NE, 68588-0491, United States

Bahar Kara, Bilkent University, Department of Industrial Eng, Ankara, 06800, Turkey

Ozlem Ergun, Northeastern University, Mechanical and Industrial Engineering, Boston, MA, 02115, United States

## ■ SD74

West Bldg 212A

### Advances on Resilient Infrastructure Networks: Modeling and Implementation

Sponsored: Multiple Criteria Decision Making

Sponsored Session

Chair: Shima Mohebbi, PhD, University of Oklahoma, Norman, OK, 73019, United States

#### 1 - Resilience Analyses of Interdependent Water-Transportation Infrastructures: Simulation-Optimization Approach

Shima Mohebbi, University of Oklahoma, 202 W. Boyd St., Room 124, Norman, OK, 73019, United States, leili soltanishehat

This study develops agent-based simulation-optimization models to evaluate the resilience of water and transportation networks by considering their physical-socioeconomic interdependencies. We first analyze water and transportation infrastructures using network measures. Different network failure scenarios, based on the degree of interdependency, will be simulated and resilience curves

for restoration strategies will be analyzed. A case study will be demonstrated in the City of Tampa, FL.

#### 2 - Bi-objective Optimization for Traffic Signal Restoration After Disruptive Events

Tingting Zhao, University of South Florida, 4202 E. Fowler Avenue, ENB 118, Tampa, FL, 33612, United States

A bi-objective optimization problem is formulated for traffic signal restoration sequence design after disruptive events. Both instantaneous resilience measure (Maximum Delay During Restoration) and accumulated resilience measure (Accumulated Total Delay) are optimized to provide various perspectives for decision maker to restore transportation system effectively with limited resources. Network-wide system performance is evaluated based on traffic simulation. NSGA-II is applied to solve this bi-objective optimization problem without enumerating all possible restoration sequences.

#### 3 - A Hybrid Machine Learning Approach to the Stochastic Network Design Problem for Mitigation Strategies

Charles D. Nicholson, University of Oklahoma, Norman, OK, United States, Alexander Rodriguez

A new paradigm for stochastic network mitigation is proposed. The approach leverages realizations from scenario event simulations to develop a probabilistic framework that supports constrained decision making. This framework incorporates component fragilities, correlated failures, and other physical aspects that affect failure probabilities. Machine learning is used to enable metaheuristic search for high-quality mitigation strategies in a discrete solution space.

#### 4 - Resilient Transportation Network Design Against Hurricane Disruptions

Yusuf Secerdin, University of Miami, 1251 Memorial Drive McArthur, Engineering Building Room 271, Coral Gables, FL, 33146, United States, Murat Erkoc

From the logistics network perspective, hurricanes significantly differ from other natural disasters in that they emerge as progressive events sweeping across regions. This distinct aspect calls for new adaptive transportation design procedures across time and space. In this study, we propose new models and efficient solution methodologies at both strategical and tactical levels for hurricane-prone logistics networks. The strategic level concerns designing resilient logistics networks and the tactical level involves rescheduling and rerouting as a response to hurricanes.

## ■ SD75

West Bldg 212B

### What if Type of Analyses for Assessing Events, Operations, and Effects

Sponsored: Military and Security

Sponsored Session

Chair: Gitanjali Adlakha-Hutcheon, Department of Defence, ON, K2H 8G1, Canada

#### 1 - Revisiting the Largest Non-nuclear Explosion

Derek Baingo, DRDC, halifax, NS, Canada, Baingo, DRDC

What if the Halifax Explosion of 1917 were to occur today? How would contemporary urban population and modern infrastructure be affected? By virtually recreating the catastrophic event from a century ago we can apply the lessons learned to better plan, design and build the cities of tomorrow.

#### 2 - A Means to Work on FATE

Gitanjali Adlakha-Hutcheon, Department of Defence, 60 Moodie Drive, Ottawa, ON, K2H 8G1, Canada

Futures Assessed alongside socio-Technical Evolutions (FATE) is a method developed by a NATO Systems Analysis Studies Panel (SAS-123). It entails studying the interactions between diverse futures and socio-technical evolutions concurrently to provide decision-makers with input on socio-technical disruptors in the context of described futures. Examples of emerging technologies and their fate in about 15 years from today will be presented.

#### 3 - Modeling Mission Effects Chains

Mark Gallagher, US Air Force, Doug Fullingim, David Quick

We discuss building a detailed series of events to represent various mission effect chains including kill chains. Adding parallel redundancies where multiple systems are available may provide an improved measure of realized mission effects for the Air Force. The horizontal (series) assessment indicates the ability to accomplish various mission. A vertical assessment (parallel redundancy) provides the basis for the mission-area health. Additionally, this mission effect chain dependencies could provide an improved basis for estimating dependencies between mission areas within the Air Force.

#### 4 - Capability Analysis for Canada's Special Operations Forces

Ramzi Mirshak, DRDC, Centre for Operational Research and Analysis, Ottawa, ON, Canada

The Canadian Special Operations Forces Command (CANSOFCOM) is developing its future operating concept. To guide this evolution, wargames were used to review capabilities of key missions both now and in the future. Assessments included ordinal scoring of criteria and gathering of comments. We present the methods and approach used, including efforts to minimize respondent bias.

#### ■ SD76

West Bldg 212C

### New Developments in Planning Production and Inventories

General Session

Chair: Reha Uzsoy, North Carolina State University, Raleigh, NC, 27695-7906, United States

#### 1 - Planning Releases during Product Transitions in Semiconductor Manufacturing

Atchyuta B. Manda, North Carolina State University, Campus Box 7906, Raleigh, NC, 27695-7906, United States, Reha Uzsoy

We use simulation optimization to model the introduction of a new product into an operating semiconductor manufacturing facility, which can have significant adverse effects on both current and new products. Our results show that planning releases by simulation optimization model yields significant improvements in performance over simple alternatives, and provides intuitive solutions.

#### 2 - A Matheuristic for Integrated Production Planning and Order Acceptance Decisions

Lars Moench, Professor, University of Hagen, Universitaetsstrasse 1, Hagen, 58097, Germany, Hung-Kai Wang

We discuss a production planning model with load-dependent lead times. Order acceptance decisions with respect to flexible due dates are allowed in addition to release decisions. We show that the resulting production planning problem is NP-hard. A variable neighborhood search (VNS) technique is hybridized with linear programming to solve large-sized problem instances. Results of computational experiments for problem instances that are derived from a scaled-down wafer fab model are presented. The results demonstrate that the proposed matheuristic outperforms time-based decomposition approaches from the literature

#### 3 - Optimizing End-item Inventory Control under Rolling Scheduling

A.G. de Kok, Eindhoven University of Technology, Eindhoven, Netherlands

We discuss a simulation-based methodology to optimize end-item inventories in multi-item multi-echelon inventory systems. We build on a sufficient condition for the Newsvendor equation to hold for end-items. This condition requires that a change in an end-item control parameter yields the same change in the net stock of this end-item at each point in time. This sample path property can be exploited for an efficient simulation-based approach to find the optimal end-item inventory control parameters.

#### 4 - Extending Clearing Functions by Including the Process History: Approaches and Research Gaps

Hubert Missbauer, University of Innsbruck, Universitaetsstrasse 15, Innsbruck, 6020, Austria

The fit of clearing functions to empirical or simulated data can be improved substantially by including explanatory variables that reflect the history of the process prior to the period under consideration. We show by means of numerical examples that the resulting multi-dimensional clearing functions cannot be integrated into existing clearing function models in a straightforward manner. Using simulation results we elaborate on the discrepancy between clearing function fit and performance of the order release model. These results, together with some structural properties of one-dimensional clearing function models, raise the question what clearing functions really are.

#### 5 - Reenactment Fluid Flow Simulation in Semiconductor Manufacturing

Ivo Adan, Eindhoven University of Technology, Den Dolech 2, Eindhoven, 5600 MB, Netherlands, Jelle Adan, Stephan Sneijders, Alp Akcay

We present a reenactment fluid-flow simulation-based method to optimize buffer sizes in a semi-conductor assembly line. The optimization method is a combination of a discrete-event fluid-flow simulation model and a multi-start search algorithm. The method is applied to a real-world case in semiconductor manufacturing.

#### ■ SD77

West Bldg 213A

### Disaster Operations Management

Sponsored: Public Sector OR

Sponsored Session

Chair: Christopher Zobel, Virginia Tech, Blacksburg, VA, 24061-0235, United States

Co-Chair: Andrew N. Arnette, University of Wyoming, Laramie, WY, 82071-2000, United States

#### 1 - Extensions to Pre-Positioning Disaster Relief Asset Optimization Model

Andrew N. Arnette, University of Wyoming, 1000 E. University Avenue, Dept 3275, Laramie, WY, 82071-2000, United States, Christopher Zobel

In this work, we extend an existing model for disaster relief asset pre-positioning so that it applies to a range of different types of resources, some of which may be perishable or substitutable. The relative performance of the general model formulation is examined with respect to problems such as allocating medical supplies to support post-disaster relief efforts.

#### 2 - Forecasting for Disaster Management

Nezih Altay, DePaul University, 1 E. Jackson Blvd., Driehaus College of Business, Chicago, IL, 60604, United States

We present the results of a structured literature review on the use of forecasting methods in for disaster management. Based on our findings we identify research gaps and make recommendations for future research.

#### 3 - Modeling Cascading Failures and Recovery of Interconnected Systems: Case Study of Puerto Rico after Hurricane Maria

Felipe Aros-Vera, Ohio University, 277 Stocker Center, 1 Ohio University, Athens, OH, 45701, United States, Shital Thekdi

Understanding interdependencies and cascading effects is of key importance for the design of critical infrastructure and further response and recovery from disruptions. This work studies these interdependencies using network design and risk-management tools. The presentation includes empirical evidence and a case study of interdependent infrastructure systems after Hurricane Maria in Puerto Rico.

#### 4 - Illicit Drug Abuse and Seizure Patterns: Insights from Data

Hossein Najmi, University of North Texas, Denton, TX, United States, Shailesh S. Kulkarni, Debjit Roy

Approximately 90 people die every day in the USA as a result of illicit drug abuse and in 2017, President Trump declared the opioid crisis a health emergency. However, there are few studies on the patterns of drug seizure, especially using advanced analytics. To address this limitation, we collected data on all drug seizures between 2010-2016 at the state level, classified them based on the Drug Schedule of the Drug Enforcement Administration (DEA) and performed data analysis on over hundred thousand data points to gain insight into the dynamics of drug seizure. By studying patterns, this study tries to develop a potential tool to increase seizure amounts and to help better control the drug disaster.

#### ■ SD78

West Bldg 213B

### Location Models II

Sponsored: Location Analysis

Sponsored Session

Chair: Zvi Drezner, California State University-Fullerton, Fullerton, CA, 92834, United States

#### 1 - A Cover Based Competitive Facility Location Model with Continuous Demand

Zvi Drezner, California State University Fullerton, Steven G. Mihaylo College of Business and Economics, Dept of ISDS, Fullerton, CA, 92834, United States, Tammy Drezner, Atsuo Suzuki

We propose and solve a competitive facility location model when demand is continuously distributed in an area and each facility attracts customers within a given distance. This distance is a measure of the facility's attractiveness level which may be different for different facilities. The market share captured by each facility is calculated by two numerical integration methods. These numerical approaches can be used for evaluating functional values in other Operations Research models.



**2 - Sequential BTST Algorithm for the Multiple War Problem**

Atsuo Suzuki, PhD, Nanzan University, Zvi Drezner

We apply the BTST (Big Triangle Small Triangle) method to the multiple Weber problem with attraction and repulsion (WAR). We formulate a variation of the WAR problem where several existing facilities are located in an area. The customers access to the nearest facility. The problem is to find the location of a new facility so as to minimize the weighted sum of the distances from the customers to their nearest facilities. We apply the BTST method to the problem. By solving the problem sequentially, we obtain an approximate solution of the multiple WAR problem.

**3 - Recent Results on Solving the Quadratic Assignment Problem using Graphics Processing Unit Clusters on the Blue Waters Supercomputer**

Rakesh Nagi, University of Illinois Urbana-Champaign, 8 Transportation Building, 104 S. Mathews Ave., Urbana, IL, 61801, United States, Ketan Date

We discuss parallel implementations of RL2 formulation and branch-and-bound algorithm for solving the Quadratic Assignment Problem (QAP). Our parallel architecture consists of NVIDIA Graphics Processing Unit (GPU) clusters on the Blue Waters supercomputer at the University of Illinois at Urbana-Champaign. We implement a “distributed Dual Ascent algorithm for the GPUs, which shows excellent parallel speedup, and can effectively solve some of the well-known QAPs from the literature.

**4 - Computational Results for Solving the Euclidean Distance Min-Max Location Problem with Fixed Distances in N-Dimensions**

Mark Cawood, Clemson University, 220 Parkway Drive, Clemson, SC, 29634-0975, United States, P. M. Dearing

Computational results for primal and dual algorithms are presented for the problem, also called the minimum covering Euclidean ball of a set of Euclidean balls in n-dimensions. Both algorithms search along a directed path that is either a ray or a hyperbola. The step size is computed explicitly at each iteration.

**Monday, 8:00AM - 9:30AM****■ MA01**

North Bldg 121A

**Bayesian Machine Learning**

Sponsored: Optimization/Optimization Under Uncertainty

Sponsored Session

Chair: Matthias Poloczek, University of Arizona, Tucson, AZ, 85721, United States

**1 - Continuous Multi-task Bayesian Optimization with Correlation**  
Juergen Branke, University of Warwick, UK, Warwick Business School, Orms Group, Coventry, CV4 7AL, United Kingdom, Michael Pearce

We consider the problem of simultaneously identifying the optima for a set of correlated tasks, where the performance of a particular input parameter on a particular task can only be estimated from noisy samples. We propose a general multi-task Bayesian optimization framework and two myopic sampling procedures that determine task and parameter values for sampling, in order to efficiently find the best parameter setting for all tasks simultaneously.

**2 - Bayesian Optimization of Combinatorial Structures**

Ricardo Baptista, Massachusetts Institute of Technology, Cambridge, MA, 02139, United States, Matthias Poloczek

The optimization of expensive-to-evaluate black-box functions over discrete domains is a ubiquitous task in machine learning and engineering. The combinatorial explosion of the search space and costly function evaluations pose challenges for current techniques. In this talk we will propose Bayesian optimization of combinatorial structures (BOCS). Our algorithm is based on an adaptive statistical model that identifies useful combinatorial structures even when data is scarce, and a scalable acquisition function that uses semidefinite programming. We will also present experimental results demonstrating that BOCS outperforms other methods from combinatorial and Bayesian optimization.

**3 - Bayesian Optimization with Expensive Integrands**

Saul Toscano, Cornell University, Ithaca, NY, 14850-5645, United States, Peter Frazier

We propose a Bayesian optimization algorithm for objective functions that are sums or integrals of expensive-to-evaluate functions, allowing noisy evaluations. These objective functions arise in multi-task Bayesian optimization for tuning machine learning hyperparameters, optimization via simulation, and sequential design of experiments with random environmental conditions. Our method is average-case optimal by construction when a single evaluation of the integrand remains within our evaluation budget. We also show consistency of our method for objective functions that are sums. In numerical experiments, our method performs as well or better across a wide range of problems.

**■ MA02**

North Bldg 121B

**Policy Search – Solving Stochastic Optimization by Searching Over Parameterized Classes of Policies**

Sponsored: Optimization/Optimization Under Uncertainty

Sponsored Session

Chair: Warren B. Powell, Princeton University, Princeton, NJ, 08544, United States

**1 - Learning to Learn How to Bid: Efficient Meta-learning based on Policy Search in Adaptive Algorithms for Sponsored Search Auction Bidding**

Donghun Lee, Princeton University, 11 Lawrence Drive, Apt 503, Princeton, NJ, 08540, United States

In online optimization problems where the cost of obtaining examples is accounted for, the need for better efficiency in learning algorithm becomes clear. Contrary to traditional big-O notation asymptotic sample complexity analysis, we take practical perspective to efficiency: learning algorithms become more efficient if its performance is improved over less iterations and samples. We propose a meta-learning framework that improves the practical efficiency of a given generic learning algorithm by finding better parameters for the algorithm. We evaluate the meta-learning framework in adaptive bidding algorithms deployed in sponsored search auctions such as Google Adwords platform.

**2 - Structured Actor Critic for Managing and Dispensing Public Health Inventory**

Yijia Wang, University of Pittsburgh, 331 Devonshire Street, Pittsburgh, PA, 15213, United States, Daniel Jiang

Public health organizations face the problem of dispensing medications to groups of affected populations during emergency situations, typically in the presence of complexities like demand stochasticity and limited storage. We formulate an MDP model with two levels of decisions: the upper-level decisions come from an inventory model that “controls” a lower-level problem that optimizes dispensing decisions. We then derive structural properties of the MDP model and propose an ADP algorithm that leverages structure in both the policy and the value space.

**3 - Parametric Cost Function Approximations for Multistage Stochastic Programming**

Saeed Ghadimi, PhD, Princeton University, Princeton, NJ, 08544, United States, Warren B. Powell, Raymond Theodore Perkins

The parametric cost function approximation represents an alternative to stochastic lookahead models that represent the foundation of stochastic programming. Parametric CFAs require some intuition into how uncertainty might affect the optimal solution.

**4 - Adaptive Aggregation with Exogenous Transition Uncertainty**

Bing-Zhen (Amy) Zhang, Cornell University, Ithaca, NY, United States, Itai Gurvich, Huseyin Topaloglu

Approximation is often used in dynamic programming due to the high computational cost for high-dimensional problems, incurring a loss in optimality. However when transition probabilities are inaccurate due to limited empirical data, even the exact model would have produced suboptimal results. We look at the interplay of the two when applying approximation, specifically state aggregation, in the presence of model uncertainty; we show that aggregation will only cause limited additional loss, if any, and propose selection procedure for an aggregation mechanism that reduces such loss.

**■ MA03**

North Bldg 121C

**Advances in Crowdfunding Research**

Sponsored: Technology, Innovation Management &amp; Entrepreneurship

Sponsored Session

Chair: Philipp Cornelius, Rotterdam School of Management, Rotterdam, Netherlands

**1 - Designing Crowdfunding Platform Rules to Deter Misconduct**

Simone Marinesi, Assistant Professor of Operations Management, The Wharton School, University of Pennsylvania, Philadelphia, PA, 19103, United States, Elena Belavina, Gerry Tsoukalas

Lacking credible rule enforcement mechanisms to punish entrepreneurial misconduct, existing reward-based crowdfunding platforms can leave campaign backers exposed to two sources of risk: the risk that entrepreneurs run away with backers' money (funds misappropriation) and the risk of product misrepresentation (performance opacity). We examine the adverse consequences of both misconduct risks and propose practically implementable platform designs aimed at curbing their harmful effects.

## 2 - An Analysis of Product Innovation as Recombinant Search using Topic Modelling

Philipp Cornelius, Rotterdam School of Management, Rotterdam, Netherlands

Product innovation is often understood as the recombination of components such as ideas, knowledge, input factors, and technologies. An important question is whether certain recombination patterns increase innovation success. The existing literature has predominantly studied recombination of technologies using patent data. I extend this literature by studying recombination during the development of new consumer products. Interestingly, recombination strategies that create successful technologies (such as patents) do not always coincide with product success.

## 3 - Revenue Management in Crowdfunding

Jiding Zhang, The Wharton School, 3730 Walnut St, 500 Jon M. Huntsman Hall, Philadelphia, PA, 19104, United States, Sergei Savin, Senthil Veeraraghavan

Crowdfunding, a mechanism in which funds are raised online using small donations from a large number of individual donors, has recently emerged as a popular approach to funding new ideas. In our paper, we model a setting where a creator of a crowdfunding project selects the amount of contribution it requests from donors and the duration of crowdfunding campaign with the goal of maximizing the raised amount. Our analysis provides project creators with detailed, practical, and intuitive guidelines on how to successfully manage the revenue generation process in a crowdfunding campaign.

## 4 - Learning as a Signal in Online Debt Market

Qiang Gao, Baruch College, City University of New York, 55 Lexington Ave, New York, NY, 10010, United States

Abstract not available.

## ■ MA04

North Bldg 122A

## Algorithmic and Polyhedral Analysis of Applied MIP Problems

Sponsored: Optimization/Integer and Discrete Optimization

Sponsored Session

Chair: Manish Bansal, Virginia Tech., Blacksburg, VA, 24060, United States

## 1 - Recent Advances on Solving Generalizations of the Single Item Capacitated Lot-sizing Problem

Kartik Kulkarni, Virginia Tech, Manish Bansal

In this talk, we present our recent advances on solving a generalization of the classical single-item economic lot-sizing problem where the total production capacity in each period can be the summation of some binary multiples of several capacity modules of different sizes. We also develop a new algorithm for the lot-sizing problem with piecewise concave production costs and concave holding costs. Finally, we present results of our computational experiments performed on the aforementioned problems.

## 2 - Multi-module Capacitated Network Design Problem and Its Generalizations

Haochen Luo, Texas A&M University, College Station, TX, United States, Kiavash Kianfar

In this work, we consider the multi-module capacitated network design (MMND) problem, where minimum cost flows and flow transfer capacities are to be decided on a network and capacities are composed of multiples of differently sized modules. We also study generalizations of MMND to networks with special requirements so that more complicated decisions need to be made. For both MMND and its generalizations, we introduce new classes of facet-defining valid inequalities not obtainable from polyhedral results in previous research. We present computational results that show the effectiveness of the new classes of inequalities for MMND and its generalizations.

## 3 - On the Robust Single Machine Scheduling Problem with Relative Robust Deviation

Juliana Arango, Clemson University, 211 Fernow St, Clemson, SC, 29634, United States, J. Cole Smith

We consider a single machine scheduling environment where the performance criterion is the total flow time, and processing times are uncertain but belong to a distinct interval for each job. We consider the case in which the uncertainty level in the problem is limited by enforcing the condition that only a constant number of jobs can have a processing time greater than the interval's lower bound. We examine characteristics of the problem for maximizing regret given a job processing sequence, and subsequently explore algorithms for minimizing maximum regret.

## 4 - Remote Microgrid Design Optimization under Photovoltaic and Load Uncertainty

Alexander Zolan, University of Texas-Austin, Austin, TX, United States, David Morton, Michael S. Scioletti, Amanda Hering

We consider a microgrid that consists of a battery, photovoltaic (PV) systems, and diesel generators, and optimize the components it comprises and a corresponding dispatch strategy at hourly fidelity to minimize procurement, operations and maintenance, and fuel costs. We use historical weather data to generate base load and PV system power output scenarios. We present a case study with weather profiles from different locations and show that solutions to instances that account for these uncertainties produce a lower-cost, more robust solution than solutions which use point forecasts as input.

## ■ MA05

North Bldg 122B

## Large-Scale Optimization Algorithms

Sponsored: Optimization/Linear and Conic Optimization

Sponsored Session

Chair: Yuyuan Ouyang, Clemson University, Clemson, SC, United States

## 1 - Quadratic Averaging for Smooth Convex Optimization

Michael Eldredge, Clemson University, Clemson, SC

First-order methods have been a popular research area in recent years, due to their efficiency on solving big data optimization problems. There had been many studies on designing efficient gradient based algorithms and understanding their performance. In this talk, we consider the interpretation of a class of accelerated gradient methods, by extending recent studies on quadratic averaging and estimating sequences. Based on the fact that many gradient based algorithms can be interpreted as designs of sequences of quadratic approximation, we design a quadratic averaging framework for solving smooth convex optimization with optimal performance.

## 2 - A Modified Conditional Gradient Sliding Method for Structured Convex Optimization

Hamid Nazari, Clemson University, Clemson, SC, 29631, United States, Yuyuan Ouyang

Based on the conditional gradient sliding (CGS) method proposed by Lan and Zhou, we design a modified CGS method for structured convex optimization. Similar as the CGS method, when minimizing structured convex functions, the proposed method is able to skip some time-consuming operations from time to time. Our modification is mainly on the acceleration technique of the sliding scheme. We prove that the convergence rate of the proposed method is at least as good as the CGS method. Some preliminary computational results comparing the proposed method and CGS will also be presented.

## 3 - Inexact Augmented Lagrangian Method for Convex Optimization

Yangyang Xu, Rensselaer Polytechnic Institute, Department of Mathematical Sciences, 110 8th Street, Troy, NY, 12118, United States,

In this talk, I will present inexact ALMs for convex programs with both equality and inequality constraints. For these problems, we establish the global convergence rate of inexact ALM and estimate its iteration complexity in terms of the number of gradient evaluations. We first establish an ergodic convergence rate result. By relating to the inexact proximal point algorithm, we also show a nonergodic convergence rate result of inexact ALM that uses geometrically increasing penalty parameters. The nonergodic iteration complexity result is in the same order as that for the ergodic result. Numerical tests on QCQP are conducted to compare the performance of the inexact ALM with different settings.

## 4 - Random Gradient Extrapolation for Distributed and Stochastic Optimization

Yi Zhou, ISyE Ga Tech, 755 Ferst Drive, NW, Atlanta, GA, 30332, United States, Guanghui Lan

In this talk, we consider a class of finite-sum convex optimization problems defined over a multiagent network with  $m$  agents connected to a central server. Our major contribution is to develop the random gradient extrapolation method (RGEM), which does not require any exact gradient evaluation even for the initial point, but achieve the optimal linear rate in terms of the number of gradient evaluations. For stochastic case, RGEM maintains the optimal sublinear rate in terms of the number of stochastic gradient computations, but attains linear communication complexity. This is the first time that these complexity bounds have been obtained for distributed and stochastic optimization problems.

## ■ MA06

North Bldg 122C

### Decomposition in Large-Scale Computational Optimization

Sponsored: Optimization/Computational Optimization and Software  
Sponsored Session

Chair: Matthew Galati, SAS Institute, Inc., Glen Mills, PA, 19342, United States

#### 1 - Decomposition Algorithm for a Capacity Expansion Problem with Permanent and Temporary Capacities

Rahman Khorramfar, PhD Student, NC state University, 2804  
Brigadoon Dr, 1, Raleigh, NC, 27606, United States, Osman Ozaltin

We study a type of stochastic capacity expansion problem where there are multiple capacities to open in each planning period. We consider capacities of temporary nature and permanent capacities, and formulated the model as a multi-stage mixed integer stochastic program with uncertain demand. We apply Dantzig-Wolfe decomposition algorithm to solve the problem. We also extended our model to include a mean-risk objective in order to reflect the sensitivity of decision makers to risk factors. Computational results are presented for different applications.

#### 2 - Dantzig Wolfe Decomposition Approach to Inland Waterway Disruption

Liliana Delgado Hidalgo, Universidad del Valle, Cl. 13 #100-00,  
Cali, 760001, Colombia

We study inland waterway disruption response to redirect disrupted barges to available terminals and prioritize offloading to minimize total cargo value loss. We formulate a mixed integer linear programming model as a heterogeneous vehicle routing problem with time windows (HVRPTW) and working to reformulate the HVRPTW via Dantzig-Wolfe decomposition approach to explore advantages of the Branch-and-Price and column generation approaches. A case example is presented to illustrate our approach and findings.

## ■ MA07

North Bldg 123

### Optimizing over Networks with Dynamics

Sponsored: Optimization/Network Optimization  
Sponsored Session

Chair: Christopher Quinn, Purdue University, West Lafayette, IN, 47907, United States

#### 1 - Optimal Versus Selfish Resource Allocation Dynamics Over Networks

S. Rasoul Etesami, University of Illinois at Urbana-Champaign,  
Urbana, IL, United States

Motivated by many emerging resource allocation problems such as web caches and peer-to-peer networks, we consider and study optimal and selfish resource allocation over a network of agents. In this model the nodes can store only a limited number of resources while access the remaining ones through their neighbors. We first study the complexity and approximability of the optimal resource allocation. We then extend our results to selfish setting by formulating the problem as a noncooperative game. We show that such a game always admits a pure-strategy Nash equilibrium and device stochastic learning dynamics to obtain one of such equilibrium points.

#### 2 - Dynamic Public Learning in Networks of Strategic Agents

AMIR Ajorlou, Massachusetts Institute of Technology, 32 Vassar  
Street, 32-D569, Cambridge, MA, 02139, United States,  
Ali Jadbabaie

There are abundant sources of information (e.g., news channels, social networks, online forums, surveys, and data bases), with every person having access to a personalized set of the sources. The aggregate action of the whole population partially accumulates the information shared within different information communities. An interesting question here is how the quality of information aggregation is affected by the influences between and within different information communities. We show that the inter-community interactions exhibit a double-edged effect that may result in a phase transition in quality of learning between different information-action structures.

#### 3 - Sparse Modeling of Network Interactions

Christopher Quinn, Purdue University, 315 N. Grant Street,  
West Lafayette, IN, 47907, United States

There are many natural and emergent systems with complex interactions between components. It is often easier to conduct observational than experimental studies. However, there are significant statistical and computational challenges in modeling and characterizing the interactions from observational data. In this talk, we will discuss recent methods to efficiently and non-parametrically identify sparse network approximations from data, with guarantees of optimality under certain conditions.

#### 4 - On Incentivized-social-influence-based Programs to Promote Behavioral Changes: A Case Study for Incentivizing Households to Save Energy

John Fontecha, University at Buffalo, 413 Bell Hall, Buffalo, NY, 14260, United States, Manjunath Jois, Alexander Nikolaev,  
Jose Luis Walteros

We present a social influence program that allocates investments as random economic incentives for a targeted community to promote changes in its energy-spending behavior. By design, an energy provider funds the program; all the members of the community are eligible to receive an incentive (win); each round of the program features many winners; the winners are chosen randomly but active savers are more likely to win; customers are informed of the winnings in their neighborhoods, fueling the program's reach. We provide the theoretical basis for the design and operation of such programs and develop methods to optimize their impact by modeling their dependence on the investment allocation strategy.

#### 5 - Workforce Management under Social Link Based Corruption

Abhinav Perla, University at Buffalo, 342 Bell Hall, University at  
Buffalo, North Campus, Buffalo, NY, 14260, United States,  
Alexander Nikolaev, Eduardo Pasillao

Development of relationships enabling corrupt behavior can be a hindrance to the productivity of an organization. This work introduces the Link Based Corruption (LBC) model, offering a perspective to curb corruption through workforce rotation. The agents are assumed to be embedded into a directed peer-to-peer monitoring network. Corruption is taken to be a threat whenever an agent and their supervisor(s) are all corruption-prone; once they identify each other as such, which takes time, a productivity loss takes place. This work addresses the policy-maker's problem of fixing the agent monitoring structure and timing the workforce rotation so as to minimize the expected long-time loss.

## ■ MA08

North Bldg 124A

### Infrastructure Optimization

Sponsored: Optimization/Network Optimization  
Sponsored Session

Chair: Robert Mark Curry, Clemson University, Clemson, SC, 29634, United States

#### 1 - Robust Location of Transparent Interdictions on a Shortest Path Network

N. Orkun Baycik, Shenandoah University, Winchester, VA,  
United States, Kelly Sullivan

We study a shortest path network interdiction problem in which the follower seeks to find a path of minimum length on a network and the leader seeks to maximize the follower's path length by interdicting arcs. We consider placement of interdictions that are not visible to the follower; however, we seek to locate interdictions in a manner that is robust against the possibility that some information about the interdictions becomes known to the follower. We formulate the problem as a bi-level program, and apply a Benders decomposition approach to optimally solve it. We derive supervalid inequalities to improve the performance of the algorithm and test the algorithm on grid networks and acyclic graphs.

#### 2 - Two-stage Stochastic Interdependent Networks Mitigation and Restoration

Cheng-Lung Chen, University of Central Florida, Orlando, FL,  
United States, Qipeng Zheng, Alexander Veremyev,  
Vladimir Boginski

We propose a two-stage stochastic program for determining the optimal mitigation and restoration strategy on two-layer interdependent networks with cascading node failure caused by random disruption. Previous studies mainly focused on either static or deterministic type of network failure, while our model features a dynamic failure propagation given initial stochastic node disruption. The first-stage problem allows capacity expansion and node fortification to mitigate the impact of disruption, while the objective of second-stage is to restore network performance with minimum costs. We propose a delayed cut generation algorithm with various types of cutting plane to solve the problem.

#### 3 - A Post Disaster Infrastructure Restoration Model: The Interdependent Integrated Network Design and Scheduling Problems with Machine Movement.

Aniela Garay Sianca, University of Arkansas, Fayetteville, AR,  
72701, United States, Sarah G. Nurre

Over the past years, post-disaster operations research models have become necessary due to the increasing number of disasters. We propose a new optimization model that looks to schedule work crews to restore damaged components on a set of interdependent networks while explicitly considering the availability and restoration of the transportation network which enables work crew movement. On realistic data representing interdependent infrastructure networks in Panama, we perform computational experiments to deduce insights and show improvement as compared to existing restoration models.



#### 4 - Tri-level Optimization for Enhancing Interdependent Network Resilience

Nafiseh Ghorbani Renani, The University of Oklahoma, 202 West Boyd St. room 124, Norman, OK, 73019, United States, Kash Barker, Andres David Gonzalez

The reliability and resilience infrastructure networks are a growing concern among communities due to the occurrence of disruptions. Resilience is often thought of as the ability to withstand a disruption and recover quickly from the disruption. The vulnerability could describe the extend to which a network is disrupted, and recoverability could describe its trajectory of recovery. As such, we propose a tri-level protection/interdiction/restoration to represent decisions made (i) by a defender before a disruption to reduce network vulnerability, (ii) by an attacker to effectively disrupt the network, and (iii) by a defender after the disruption to enhance recoverability.

#### ■ MA09

North Bldg 124B

#### Large-scale Optimization

Sponsored: Optimization/Nonlinear Programming  
Sponsored Session

Chair: Aryan Mokhtari, Massachusetts Institute of Technology, Cambridge, MA, 02139, United States

Co-Chair: Alejandro Ribeiro, Wynnwood, PA, 19096, United States

##### 1 - Theory on the Absence of Spurious Optimality

Cedric Jozs, University of California, Berkeley, Berkeley, CA, United States, Ouyang Yi, Richard Zhang, Javad Lavaei, Somayeh Sojoudi

We study the set of continuous functions that admit no spurious local optima which we term global functions. They satisfy various powerful properties for analyzing nonconvex and nonsmooth optimization problems. For instance, they satisfy a theorem akin to the fundamental uniform limit theorem in analysis regarding continuous functions. Global functions are also endowed with useful properties regarding composition of functions and change of variables. Using these new results, we show that a class of nonsmooth nonconvex optimization problems arising in tensor decomposition applications are global functions (e.g. with L1 objective functions).

##### 2 - Generative Adversarial Networks (GANs) and Compressed Sensing

Alexandros Dimakis, University of Texas at Austin, Austin, TX, United States

The goal of compressed sensing is to estimate a vector from an underdetermined system of noisy linear measurements, by making use of prior knowledge on the structure of vectors in the relevant domain. For almost all results in this literature, the structure is represented by sparsity in a well-chosen basis. We show how to achieve guarantees similar to standard compressed sensing but without employing sparsity at all. Instead, we suppose that vectors lie near the range of a generative model, e.g. a GAN or a VAE. We show how the problems of image inpainting and super-resolution are special cases of our general framework.

##### 3 - Fast Nonconvex SDP Solver for Large-scale Power System State Estimation (PSSE) Problem

Hao Zhu, The University of Texas at Austin, 2501 Speedway, Austin, TX, 78712, United States

Convex relaxation to a semi-definite program (SDP) has shown great success in power flow related problems of quadratic relations. High computational complexity of SDP solver however, challenges its large-scale application in real-time monitoring such as power system state estimation (PSSE). We will introduce an accelerated solver for large-scale PSSE by leveraging recent advances on non-convex SDP formulation that allows a lower-dimensional matrix search space. The accelerated gradient descent method is adopted to iteratively solve the resultant problem, at low per-iteration complexity thanks to the problem sparsity structure therein.

##### 4 - Quantized Decentralized Consensus Optimization

Ramtin Pedarsani, UC Santa Barbara, ECE Department, UCSB, Santa Barbara, CA, 93106, United States, Amirhossein Reisizadeh, Aryan Mokhtari, Hamed Hassani

We consider the problem of decentralized consensus optimization, where the sum of  $n$  convex functions are minimized over  $n$  distributed nodes that form a connected network. We consider the case that the communicated local decision variables among nodes are quantized to alleviate the communication bottleneck in distributed optimization. We propose the Quantized Decentralized Gradient Descent (QDGD) algorithm, in which nodes update their decision variables by combining the quantized information received from the neighbors with their local information. We prove that under standard strong convexity and smoothness assumptions, QDGD achieves a vanishing mean solution error.

#### ■ MA10

North Bldg 125A

#### Interface of Operations and Finance: Optimization and Game Theory Methods

Sponsored: Manufacturing & Service Oper Mgmt  
Sponsored Session

Chair: Zhen Liu, PhD, Daniel L. Goodwin College of Business, Benedictine University, 5700 College Road, Goodwin Hall Rm 366, Lisle, IL, 60532-2851, United States

##### 1 - An Incentive Mechanism Based on Trade Credit in a Risk-averse Supply Chain under Asymmetric Information

Lian Qi, Department of Supply Chain Management, Rutgers Business School, Newark, NJ, United States, Zhihong Wang, Zhen Liu

We take the model under information symmetry as the benchmark; the trade credit incentive model under information asymmetry is constructed based on the principal-agent framework, and we obtain the optimal trade credit contract configuration and further deduce the optimal decision of the retailer. Then, we analyze the validity of the contract and the influence of the private information and risk-aversion coefficient on the contract parameters and the selling price. The study shows that when the degree of risk aversion is within a certain range, the reasonable trade credit contract designed by the supplier can effectively encourage the retailer to report its real sales cost.

##### 2 - Depth-limited Solving in Imperfect-information Games

Tuomas W. Sandholm, Angel Jordan Professor of Computer Science, Carnegie Mellon University, Pittsburgh, PA, 15213, United States, Noam Brown, Brandon Amos

A key challenge in imperfect-information games is that states do not have defined values. So, depth-limited search algorithms used in single-agent and perfect-information settings do not apply. We introduce a principled way to conduct depth-limited solving in imperfect-information games by allowing the opponent to choose among multiple strategies for the remainder of the game at the depth limit. Each of the strategies results in a different set of values for leaf nodes. This forces an agent to be robust to different opponent strategies. On a 4-core CPU and 16 GB memory, we build a master-level heads-up no-limit Texas hold'em AI that defeats many prior top AIs. Previously this required a supercomputer.

##### 3 - An Analytical Treatment of Dynamic Pricing and Learning with Menu Costs

Zhen Liu, Assistant Professor, Benedictine University Goodwin College of Business, Goodwin Hall Room 366, 5700 College Road, Lisle, IL, 60532, United States

Many firms face the problem of selling a given stock of products by a deadline. In their classic paper, Gallego and Ryzin (1994) show the optimal pricing policy is a function of the stock level and the length of the horizon. However, empirical studies show that the firms do not change their pricing policy as frequently as predicted, which leads to price stickiness. To better explain the discrepancy, we introduce menu costs into the problem and formulate it as a continuous-time impulse intensity control problem with Poisson-style demand processes. We obtain our optimal policy in threshold-type. Based upon this policy, we discuss approximation procedure for pricing policy under Bayesian learning.

#### ■ MA11

North Bldg 125B

#### Topics at the Interface of Finance, Operations and Risk Management

Sponsored: Manufacturing & Service Oper Mgmt/IFORM  
Sponsored Session

Chair: Dan Iancu Iancu, Stanford School of Business

##### 1 - Risk Propagation in the Mortgage Supply Chain and the Financial Crisis

Marco Yu Zhang, Illinois Institute of Technology, Chicago, IL, United States, John R. Birge

Securitization has often been cited as the innovation in the mortgage supply chain that increased mortgage supply and the fragility of the network in leading to the financial crisis of 2008-2009. This supply-driven explanation, however, misses an important demand driver caused by drop in funding ratios increased risk-taking incentives for pension funds. This talk will describe a supply chain model to explain this phenomena and will present empirical support for the dominance of the demand effect.

**2 - Cash Hedging in a Supply Chain**

Yixuan Xiao, City University of Hong Kong, 83 Tat Chee Avenue, Kowloon, Hong Kong, Panos Kouvelis, Xiaole Wu

We study hedging cash flow risks in a supply chain where firms invest internal funds to improve production efficiencies. We offer a decomposition framework to capture the cost reduction and flexibility effect of hedging. It allows us to understand how a firm's hedging choice depends on its supply chain partner's decision, and how such interaction is affected by supply chain characteristics such as market size, cash flow volatility and correlation.

**3 - Financial Incentives to Avoid Major Quality Problems in a Supply Chain**

Matthew Sobel, Case Western Reserve University, Cleveland, OH, United States, Susan Slotnick

Manufacturers who outsource components incur risks as well as benefits. If the supplied product has a major quality defect, the adverse effect on the manufacturer's reputation reduces its market share. This paper presents a discrete-time model of a buyer who collaborates with a sole supplier to avoid quality problems by paying a higher per-unit purchase price to the supplier and/or paying the supplier a lump sum contingent on the absence of a major quality defect. Analytical results include an optimal risk-posture policy for which the buyer should use only one of these financial incentives or the other. Computational results provide insights about the relationship of that optimal policy to various parameters.

**■ MA12**

North Bldg 126A

**Quantum Computing**

Emerging Topic: OR Frontiers

Emerging Topic Session

Chair: Aaron Lott, D-Wave Systems Inc., Palo Alto, CA, 9, United States

**1 - Towards Quantum-assisted Optimization and Machine Learning on Google Quantum Cloud**

Masoud Mohseni, Google Quantum AI Lab, Venice Beach, CA, United States

We present an overview of our progress quantum optimization and machine learning at Quantum AI Lab at Google. In particular, we present an end-to-end quantum-assisted optimization engine on Google Cloud Platform. Our physics-inspired approaches use an interplay of thermal and quantum fluctuations to sample from inaccessible low-energy states of spin-glass systems that encode certain hard combinatorial optimization and probabilistic inference problems. We also introduce universal discriminative quantum neural networks for classification and purification of quantum data.

**2 - Leveraging Mixed Integer Programming for Evaluating D-Wave Solution Quality**

Carleton Coffrin, Los Alamos National Laboratory, Los Alamos, NM, United States

Unconstrained Binary Quadratic Programs are a challenging class of NP-Hard discrete optimization problems with a wide variety of real-world applications and established solution methods. This work compares the performance of established Integer Programming solvers, a state-of-the-art Large Neighborhood Search heuristic, and a D-Wave QPU on a variety of BQP problem classes from the literature. The computational results suggest that the D-Wave QPU consistently produces high-quality solutions with runtimes that are comparable to the established methods.

**3 - Quantum Machine Learning at the Creative Destruction Lab**

Eric Brown, Creative Destruction Lab, Toronto, ON, Canada

Now is a critical time for the emerging technology of quantum computing. Progress in the field is being fueled increasingly by industry players seeking to capitalize on its disruptive potential. At the Creative Destruction Lab (CDL), through our Quantum Machine Learning initiative, we are incubating pre-seed ventures pursuing commercial quantum computing and its intersection with machine learning. In this talk I will introduce modern quantum computing, the CDL's approach to developing its landscape, and some of the applications being pursued by our quantum alumni ventures.

**4 - Putting Quantum Computing in Your Toolbox**

Aaron Lott, D-Wave Systems Inc., Palo Alto, CA, United States

We present an overview of the D-Wave 2000Q quantum computer architecture and discuss several novel optimization and machine learning algorithms that have been designed to leverage current and future D-Wave quantum computers. We describe the interplay between statistical physics, quantum annealing, Bayesian inference and Boltzmann machines to provide insights into areas where quantum computation and quantum simulation will play a key role in solving data-driven real-world problems.

**■ MA13**

North Bldg 126B

**Healthcare Operations**

Sponsored: Manufacturing & Service Oper Mgmt/Healthcare Operations

Sponsored Session

Chair: Michael Freeman, INSEAD, Singapore

**1 - The Impact of New Service Delivery Models on Work Hours and Quality**

Hessam Bavafa, Wisconsin School of Business, 4284C Grainger Hall, 975 University Avenue, Madison, WI, 53706, United States, Christian Terwiesch

In many professional services, an expert server such as a physician or lawyer delivers services to customers across multiple channels: in-person meetings, phone calls, and emails. In these settings, there exists a risk that work obligations encroach on the personal lives of the experts and that the quality of their work might suffer. We empirically examine these concerns in the setting of physicians providing care to patients via two channels: in-person office visits and online e-visits. Our data include 3.4 million patient encounters (more than one million of which are e-visits) covering a 8.5-year timespan.

**2 - The Impact of Bundled Payment Policy on Healthcare Operations: Evidence from China**

Jingui Xie, University of Science and Technology of China, School of Management, 96 Jinzhai Road, Hefei, 230026, China, Yiming Fan, Jingqi Wang

The paper studies the impact of bundled payment on health care spending, utilization, and quality, by using insurance claim data. We provide new evidence from China on the impact of bundled payment versus fee-for-service on health care operations. Our main results show that bundled payment reduces medical cost and length of stay in general, while increases readmission and revisit rates. Our results show that cost reduction in provincial hospitals is significant while the quality of care is maintained. However, the medical cost in country hospitals was not reduced after the implementation of bundled payment.

**3 - Physician Leadership and Operational Strategies:****Focus, Volume and Concentration in General Hospitals**

Sandra S Iz, Erasmus University, Rotterdam, Netherlands, Ludwig M. Kuntz, Michael Wittland

We consider the role of physicians in leadership positions and their influence on operational strategies pursued in general hospitals. We distinguish between volume strategies, focus strategies, and internal routing strategies and analyze how the involvement and the turnover rate of the medical director is related to the choice of these strategies.

**4 - Continuity of Care versus a Second Opinion: Evidence from the Opioid Crisis**

Katherine Bobroske, Cambridge Judge Business School, Trumpington Street, Cambridge, CB2 1AG, United Kingdom, Michael Freeman, Lawrence Huan, Stefan Scholtes

In the US, mortality from the opioid crisis is quickly eclipsing the AIDS epidemic, taking an estimated 49,000 lives in 2017 alone. Despite risk warnings, opioids continue to be frequently used in general practice. We investigate the impact of continuity of care versus a second opinion for patients with a first opioid prescription. Continuity of care is generally commended as a single doctor has full oversight into the patient's treatment plan. However, in the context of opioids, it may be difficult for a doctor who prescribed the first opioid to transition the patient to a different treatment. Using a nationwide dataset, we find that the second opinion may be a critical tool in curbing opioid dependence.

## ■ MA14

North Bldg 126C

**Innovation in Service Management and Delivery**

Sponsored: Manufacturing &amp; Service Oper Mgmt/Service Operations

Sponsored Session

Chair: Serguei Netessine, The Wharton School, Philadelphia, PA, 19104, United States

**1 - Investing in Performance: Information and Merit-based Incentives in K-12 Education**

Vanitha Virudachalam, Wharton School, OID, 3730 Walnut Street, 500 Jon M. Huntsman Hall, Philadelphia, PA, 19104, United States, Sergei Savin, Matthew Steinberg

We study performance-based contracts in a K-12 educational setting, where a school district contracts with teachers to meet student performance goals. We examine the trade-offs between information and monetary incentives faced by districts using a two-period dynamic principal-agent model, where the school district (principal) decides on the level of merit-based incentive to offer and whether to invest in assessments that provide more accurate mid-year student performance information and the teachers (agents) decide the level of effort to exert in each period. We identify settings where the benefits of the additional information justify their costs.

**2 - When to Innovate and when to Grow? Empirical Analysis of Startup Operation**

Christophe Pennetier, INSEAD, 6 Marina Boulevard, # 27-15, Singapore, 018985, Singapore, Serguei Netessine, Karan Girotra

Using a new curated dataset with more than half a million startups, we use customized text mining / machine learning techniques to identify business model changes and study their effects on startups' success. We are the first to empirically relate startup operations to performance.

**3 - Efficiency of Streethail vs. Booking Apps**

Jussi Keppo, National University of Singapore, Mochtar Riady Building, BIZ 1 8-69, 15 Kent Ridge Drive, Singapore, 119245, Singapore, Shih-Fen Cheng, Ming Hu

We study the efficiency of taxi divers to serve passengers by using streethail vs. booking apps. Our key metric is the percentage of time the taxi drivers spend in serving their passengers. We find that on average the service time of streethail and booking is about the same. Although booking technologies reduce the roaming time, the resulting response time makes the booking as efficient as streethail. We study the heterogeneity of our findings, and show that guided roaming combines the advantages of streethail and booking apps, and improves the efficiency of taxi drivers.

**4 - Reading Between the Stars: Understanding the Effect of Online Customer Reviews on Product Demand**

Hallie Cho, INSEAD, Boulevard de Constance, PhD Office, Fontainebleau, 77300, France, Sameer Hasija, Manuel Sosa

Many studies have examined quantitative customer reviews (i.e. star ratings) and found that they are a relevant source of quality information. We also examine the qualitative part of customer reviews by implementing a novel algorithm to assess the sentiment of the text and study how the interplay between sentiment and star ratings relates to product demand. Using the U.S. Automobile market data, we find that sentiment and star ratings both have a decreasingly positive effect on demand and that their interaction effect suggests they act as non-trivial complements: positive sentiments in text reviews compensate for the tendency to discount highly positive ratings.

## ■ MA15

North Bldg 127A

**Service Systems with Strategic Behavior**

Sponsored: Manufacturing &amp; Service Oper Mgmt/Service Operations

Sponsored Session

Chair: Noah Gans, University of Pennsylvania, Philadelphia, PA, 19104-6340, United States

Co-Chair: Gerry Tsoukalas, Wharton School of Business, Philadelphia, PA, 19104, United States

Co-Chair: Rowena Gan, Wharton School of Business, Philadelphia, PA, 19104, United States

**1 - Pooling Queues in Discretionary Services**

Guillaume Roels, INSEAD, Boulevard de Constance, Fontainebleau, 77305, France, Mor Armony, Hummy Song

Contrary to the classical theory of operations management, recent case studies in retail, call centers, and healthcare indicate that pooling queues may not necessarily result in less expected work in process. In this paper, we propose that this phenomenon may arise when servers choose their own capacity to trade off their capacity costs with the holding costs of customers in service (when the queue is not visible to the servers) or of all customers in the system (when the queue is visible). We show that the difference in operational performance between the two configurations is marginal when the queue is visible, but can be substantial, with a preference for dedicated queues, when the queue is not visible.

**2 - Service Delivery Platforms: Pricing, Welfare, and Revenue Implications**

Andrew E. Frazelle, Duke University-Fuqua School of Business, 540 South LaSalle Street, #4340, Durham, NC, 27705, United States, Pnina Feldman, Robert Swinney

Service delivery platforms maintain a symbiotic relationship with the existing providers in their industry. While this relationship entails cooperation between the platform and the restaurant, there is substantial opportunity for misalignment. We model the restaurant's kitchen as an M/M/1 queue with customer waiting costs. We first study the revenue maximization problem faced by a monopolist who controls both the dine-in and delivery prices and receives all revenues from the system. We then investigate means of coordinating this supply chain via different contracts between the restaurant and the platform, and we find that a two-way revenue-sharing contract coordinates the system.

**3 - Managing the Interaction of Acquisition and Retention in Customer Intensive Services**

Vasiliki Kostami, London Business School, Regent's Park, London, NW1 4SA, United Kingdom, Vasiliki Kostami, HEC Paris, Paris, France, Oded Koenigsberg

Customer acquisition affects customer retention and vice versa due to budget constraints but this is not the sole factor. Loyal customers and potential customers have different reception of prices and the quality they are offered which adds an extra layer of interaction between the two segments. We study the optimal prices and service rates in customer intensive services under the consideration of the linking between customer acquisition and retention.

**4 - Overbooking with Endogenous Demand**

Jingxing (Rowena) Gan, Wharton School of Business, University of Pennsylvania, Philadelphia, PA, 19104, United States, Gerry Tsoukalas, Noah Gans

Traditional models of airline overbooking assume exogenous demand that is not affected by the booking policy. We study how the overbooking policy can affect consumer demand ex ante. Given a rational choice model for consumers, we derive an airline's optimal booking, pricing and compensation policy for a single flight with a deterministic individual no-show rate. We model and compare two compensation schemes, a fixed scheme and an auction scheme. Our results show that the airline overbooks less when considering strategic consumer behavior as opposed to treating demand as exogenous.

## ■ MA16

North Bldg 127B

**Operations Management and Development**

Sponsored: Manufacturing &amp; Service Oper Mgmt/Sustainable Operations

Sponsored Session

Chair: Andre Du Pin Calmon, INSEAD, Fontainebleau, 77300, France

**1 - Optimizing First-mile Logistics in Smallholder Supply Chains**

Sergio Camelo, Stanford University, Stanford, CA, United States, Joann de Zegher, Dan Andrei Iancu, Daniela Saban

We study the logistics surrounding pick-ups and deliveries of palm fruit in the Indonesian smallholder palm oil supply chain. Using data from roughly 3,000 smallholder farmers and 100 transport providers from our field site in Sumatra, we reconstruct current transportation routes, and propose novel algorithms that rely on spatial or temporal optimization. We find that centralized vehicle routing algorithms can improve the transportation distances by 25%, and reduce the number of days that middlemen have to work by 30%. We expect the implementation of our results to reduce overall costs in the market, and ease the digitization of agricultural data in smallholder palm oil supply chains.



## 2 - Show or Tell: What Improves Agent Decision Making in the Mobile Money Industry? - Evidence from a Field Experiment in Tanzania

Jason Acimovic, Penn State University, 462 Business Building,  
University Park, PA, 16802, United States,  
Christopher Dalton Parker, David F. Drake,  
Karthik Balasubramanian

Two key decisions operations managers must make when designing systems to support their employees are: 1) what guidance to deliver, and 2) what kind of training (if any) to provide. We examine these choices in the context of mobile money platforms. In partnership with a Tanzanian mobile money operator, we perform a randomized controlled trial to examine how differing types of guidance and training impact the agents' inventory management. Agents who are trained in person and receive an explicit recommendation are less likely to stockout of electronic currency during the day.

## 3 - Multi Stakeholders Perspectives on the Impacts of Safety Violation: An Event Study of Manufacturing Firms

Chris Lo, Hong Kong Polytechnic University, Hong Kong, Di Fan, Yi Zhou

We conducted a safety violation event study in the US and we found market react negatively. If the violation happened in the non-Republicans states and in the presence of labour union, the abnormal returns of stock price were more negative. It is the first evidence that the political leadership could moderate firm's abnormal stock return on social issue. To confirm our prediction, we found that both the number of violations and inspections significantly decreased after a Democrats state changed to Republican state. The enforcement of safety regulation weaken in Republicans' tenure and investors reacted accordingly. It shows that a political neutral structure is necessary for social governance.

## 4 - Operations Management Challenges in a "Cloud Factory": Distributed Manufacturing of Handmade Goods in Kenya

Andre Du Pin Calmon, INSEAD, Boulevard de Constance,  
Fontainebleau, 77300, France, Victor Araman, Anton Ovchinnikov

Motivated by a social enterprise in Kenya that manufactures fashion accessories using a distributed network of artisans, we analyze the operational challenges of managing a decentralized "virtual" or "cloud factory. The artisans have limited capabilities and varying production quality, while the company faces uncertain demand. We investigate operational issues that emerge in this unique setting by formulating the scheduling problem faced by the manufacturer as a stochastic dynamic optimization problem. We present preliminary results and numerical experiments.

## ■ MA18

North Bldg 128A

## Sourcing, Inventory and Pricing in Consumer Goods Supply Chains

Sponsored: Manufacturing & Service Oper Mgmt/Supply Chain  
Sponsored Session

Chair: Candace Arai Yano, University of California-Berkeley, Berkeley, CA, 94720-1777, United States

## 1 - Wine Analytics: The Impact of Weather and Market on En Primeur Prices

Mert Hakan Hekimoglu, Rensselaer Polytechnic Institute, 110 8th Street, Pittsburgh Building, Troy, NY, 12180, United States, Burak Kazaz

Many businesses in the wine industry do not engage in wine futures (also, known as En Primeur) because they cannot predict the release prices in order to make efficient plans and purchasing arrangements. Our work provides guidance to winemakers in their price selection, and buyers (negociants, distributors, merchants) on the appropriateness of these prices. We examine empirically how weather and market fluctuations influence the release prices of fine wine. Higher temperatures and appreciation in the Liv-ex 100 index as market indicator increase prices while higher levels of precipitation reduce them.

## 2 - How Sourcing and Price Leadership Affect Optimal Store-Brand Quality

Candace Arai Yano, University of California-Berkeley, IEOR Department, 4141 Etcheverry Hall, Berkeley, CA, 94720-1777, United States, Bo Liao, Minakshi Trivedi

We study the effects of sourcing and pricing power on optimal store-brand quality under three sources (in-house, a national-brand manufacturer with a competing product, and a strategic third-party manufacturer), and under two types of price leadership (Manufacturer-Stackelberg and Retailer-Stackelberg). We characterize the retailer's optimal quality levels and their relative values across the six scenarios and present other equilibrium results. Among other things, we show that the retailer optimally uses the quality level both for differentiation and to induce competition between suppliers, and that the power to decide the source is more important to the retailer than having pricing power.

## 3 - Optimal Procurement Contracts under Hidden Information and Actions about Supply Disruptions

Xi Shan, University of Texas at Dallas, Richardson, TX, 75075, United States, Chenglin Zhang, Suresh P. Sethi

We consider a supply chain in which a retailer (the principal) facing a stochastic demand orders from a supplier (the agent) subject to supply disruption. The supplier has private information on his initial supply reliability, which he is able to improve upon when needed by an effort not observed by the retailer. We find a contract menu, consisting of an order quantity along with a transfer payment and a penalty if there is no delivery, which induces the supplier to reveal his private information. We show that the supplier under the contract would exert less than the first-best effort. Moreover, it is not optimal for the contract to require the supplier to exert an effort to become fully reliable.

## 4 - Procurement Mechanism Design for Assembler under Asymmetric Information

Jennifer K. Ryan, Dept of Supply Chain Management & Analytics, College of Business Administration, Lincoln, NE, 68588-0491, United States, Zhaolin Li, Lusheng Shao, Daewon Sun

Assembly systems are found in a variety of industries, such as consumer electronics. In many practical settings, the assembler possesses incomplete information regarding the marginal cost of each supplier. This lack of complete information poses a challenge for the assembler in designing contract mechanisms. We propose a contract that is incentive compatible in dominating strategies (ICDS), ensuring that every supplier truthfully reveals their own production cost, regardless of how the other suppliers might behave. We also introduce a hybrid mechanism, under which the complexity of the contract offered to a given supplier depends on the importance of that supplier to the assembler's profit.

## ■ MA19

North Bldg 128B

## Advances in Pricing and Revenue Management

Sponsored: Revenue Management & Pricing  
Sponsored Session

Chair: Ruxian Wang, Johns Hopkins University, Carey Business School, Baltimore, MD, 21202, United States

## 1 - Pricing of Services

Ozlem Yildiz, University of Virginia, Darden School of Business, 100 Darden Blvd. Darden School of Business., Office: FOB 189, Charlottesville, VA, 22903, United States, Dana Popescu

In this paper we analyze simple pricing strategies for access services. We characterize the optimal service (flat fee) price as well as the optimal resource (usage) price. We then identify the conditions under which service pricing outperforms resource pricing and analyze the performance of simple service and resource pricing heuristics.

## 2 - Pricing Problems under the Markov Chain Choice Model

A. Serdar Simsek, University of Texas-Dallas, Naveen Jindal School of Management, 800 W. Campbell Road, Richardson, TX, 75080, United States, James Dong, Huseyin Topaloglu

We consider three fundamental pricing problems when customers choose under the Markov chain choice model. First, for the monopolistic pricing problem, we show how to compute the optimal prices efficiently. Second, for the competitive pricing problem, we show that a Nash equilibrium (NE) exists, prove that NE prices are no larger than the prices set by a central planner and characterize NE that Pareto dominates all other Nash equilibria. Third, for the dynamic pricing problem with a single resource, we prove structural properties of the optimal prices. We also report on numerical analyses.

## 3 - Attribute-based Modeling of Product Recommendations

Sajad Modaresi, Assistant Professor of Operations Management, UNC Chapel Hill, Chapel Hill, NC, 27599, United States, Denis R. Saure, Fernando Bernstein

We study efficient real-time data collection approaches for an online retailer that dynamically personalizes the assortment offerings based on customers' attributes (e.g., gender and age). We propose policies that leverage the transaction data of customers with similar attributes to expedite the learning process and maximize revenue. We prove that the proposed policies are near-optimal and test their performance using a dataset from a large Chilean retailer.

## 4 - Pricing Ancillary Service Subscriptions

Ozge Sahin, Johns Hopkins University, 100 International Drive, R1288, Baltimore, MD, 21231, United States

We investigate heterogeneous customer choice behavior in the presence of main products, ancillary services with options of pay-per-use and subscription. Ancillary service subscriptions may result in "win-win for the firm, competitors and customers in a variety of monopolistic and duopolistic scenarios. Ancillary service subscription can help firms to better price-discriminate heterogeneous customers through different subscription decisions and subsequent main product purchase behavior.

## ■ MA20

North Bldg 129A

**Marketplaces**

Sponsored: Revenue Management &amp; Pricing

Sponsored Session

Chair: Xuanming Su, University of Pennsylvania, Philadelphia, PA, 19104, United States

**1 - Ride-hailing Networks with Strategic Drivers:****The Impact of Platform Control Capabilities on Performance**Zhe Liu, Columbia Business School, New York, NY, USA,  
Philipp Afeche, Costis Maglaras

We study the performance impact of two operational controls, demand-side admission control and supply-side repositioning control, in ride-hailing networks with strategic drivers. We characterize the system equilibria for various control regimes, show how the performance gains from these controls depend on the capacity and the network demand imbalance, and provide new results on how admission control affects drivers' repositioning decisions.

**2 - Referral and Learning on Social Network: Implications for Inventory**Guangwen Kong, University of Minnesota, 111 Church Street SE,  
Minneapolis, MN, 55414, United States, Yuanchen Su,  
Ankur Mani

We consider a firm selling differentiated products to customers whose preferences are correlated in a social network. We investigate how the network structure and customer learning influence the demand distribution and therefore have an impact on the firm's inventory decision and the optimal design of referral programs

**3 - Managing Market Thickness in Online B2B Markets**Wenchang Zhang, University of Maryland, College Park, MD,  
20742, United States, Kostas Bimpikis, Wedad Jasmine  
Elmaghraby, Kenneth Moon

Platforms can obtain sizable returns by operationally managing their market thickness (i.e., the availability of supply-side inventory). Using data from a natural experiment on a major B2B auction platform specializing in the \$424 billion secondary market for liquidating retail merchandise, we find that thickening the platform's market by closing auctions on certain weekdays increases its revenue by 7.3%, due to the bidders' participation frictions. Using structural modeling, we then study two complementary design levers to control the market thickness: (i) its listing policy, which determines the ending times of auctions, and (ii) a recommendation system.

**4 - Centralized versus Decentralized Routing in Ride-hailing Networks**Xuanming Su, University of Pennsylvania, The Wharton School,  
3730 Walnut Street, Philadelphia, PA, 19104, United States

We build a spatial equilibrium model to study traffic flows in ride-hailing networks. We consider two regimes: drivers follow a central routing plan (i.e., centralized) or choose their own directions (i.e., decentralized). Our results measure the value of centralized routing.

## ■ MA21

North Bldg 129B

**Emerging Topics in Revenue Management**

Sponsored: Revenue Management &amp; Pricing

Sponsored Session

Chair: George Chen, UT Dallas, Dallas, TX

**1 - Personalized Assortment Optimization with High Dimensional Customer's Data**Sentao Miao, University of Michigan-Ann Arbor, Ann Arbor, MI,  
48104, United States, Xiuli Chao

Motivated by online retailing with mass amount of customer's data, we study the online personalized assortment selection problem. Because the customer's data, such as browsing history, often has extremely high dimension, there are two challenges: the first is high time complexity; the second is performance of the algorithm (to maximize the total revenue). In this paper, we explicitly address these two challenges by combining an upper-confidence-bound (UCB) type algorithm with the so-called random projection method. We prove that our algorithm has low computational time and provably near-optimal performance. Numerical experiments show that our algorithm has great empirical performance.

**2 - Carpool Services for Ride-sharing Platforms**Renyu Zhang, New York University Shanghai, 1555 Century  
Avenue, Shanghai, 200122, China, Xuan Wang

We study the carpool services of a ride-sharing platform. The carpool services allow passengers heading towards the same direction to share a ride at a discount fare. We study the operational issues of a ride-sharing platform in the presence of carpool services. We show that carpool services enable the platform to achieve a larger market coverage and lower prices. Using the operational data from San Francisco, we find that carpool services could also reduce the price variabilities riders face. As two operational leverages to match supply and demand, carpool services and surge pricing are complements when demand-supply ratio is large or small, but are substitutes when demand-supply ratio is moderate.

**3 - Latent Agents in Networks: Estimation and Pricing**Ozan Candogan, University of Chicago, Booth School of Business,  
Chicago, IL, 27708, United States, Baris Ata, Alexandre Belloni

Agents in a social network consume a product that exhibits positive local network externalities. A seller has access to data on past consumption decisions/prices for a subset of observable agents, and can target these agents with discounts. The observable agents potentially interact with additional latent agents, who can purchase the same product from a different channel. Observable agents influence each other both directly and indirectly through the influence they exert on the latent part. The seller does not know the underlying network structure. We provide algorithms that allows the seller to estimate the influence structure from the available data, and improve her pricing decisions.

**4 - Real-time Spatial Dynamic Pricing for Balancing Supply and Demand in a Network**Qi Chen, London Business School, London, United Kingdom,  
Yanzhe Lei, Stefanus Jasin

Motivated by recent expansion of mobile ride-hailing apps in the taxi industry in big cities, we study a real-time spatial dynamic pricing problem where a firm who uses many units of reusable resources (e.g., taxis) in a network to serve price-sensitive customers who arrive over a finite selling season (e.g., one day) in a stochastic and nonstationary fashion. For any origin-destination pair, the quoted price equals a nominal price times an origin-specific price multiplier. The firm can dynamically change quoted prices by adaptively adjusting the price multipliers over time. We develop a Network Balancing Control that has asymptotically optimal performance and discuss some extensions.

## ■ MA22

North Bldg 130

**Revenue Management under Consumer Choice Behavior**

Sponsored: Revenue Management &amp; Pricing

Sponsored Session

Chair: Zizhuo Wang, University of Minnesota, Minneapolis, MN,  
55414, United States**1 - Consumer Choice and Market Expansion: Modeling, Optimization and Implementation**Ruxian Wang, Johns Hopkins University, Carey Business School,  
100 International Dr, Baltimore, MD, 21202, United States

The market size, measured by the number of people who are interested in the products, may be highly affected by the management strategy. We refer to this effect as market expansion. In this paper, we incorporate market expansion effect into consumer choice models and to investigate the problems on assortment, pricing and estimation.

**2 - Irrational Behavior Modeling and Decision Making**Yi-Chun Chen, UCLA Anderson School of Management,  
Los Angeles, CA, United States

Customer preferences are often assumed to follow weak rationality, which assumes that adding a product to an assortment will not increase the choice probability of a product already in that assortment. In this paper, we study a new choice model that relaxes this assumption and can model a wider range of customer behavior, such as anchoring effects between products. We develop efficient procedures for model learning and subsequent decision making. Using synthetic and real data, we show that the model can better predict customer behavior and lead to higher revenue.

**3 - Space Constrained Assortment Optimization under the Paired Combinatorial Logit Model**

Jacob Feldman, Olin Business School, United States

We study the space constrained assortment optimization problem under the paired combinatorial logit choice model. The goal in this problem is to choose a set of products to make available for purchase with the intention of maximizing the expected revenue from each arriving customer. Each offered product occupies a specific amount of space and there is a limit on the space consumed by all of the offered products. The purchasing decision of each customer is governed by the paired combinatorial logit choice model. We provide the first efficient constant factor approximation for this problem.

#### 4 - Multi-stage Assortment Problems under the Multinomial Logit Model

Yuhang Ma, Cornell Tech, 2 West Loop Road, New York, NY, 10044, United States, Nan Liu, Huseyin Topaloglu

We consider an assortment problem where we offer sets of products in multiple stages and the choice process at each stage is driven by the multinomial logit model. In particular, we have  $K$  stages. At each stage, we offer a distinct set of products. If the customer makes a purchase at a certain stage, then her choice process terminates. If the customer does not make a purchase at a certain stage, then she observes the set of products offered at the next stage. The goal is to find a set of products to offer at each stage to maximize the expected revenue obtained from a customer. We show that the problem is NP-hard and develop an FPTAS.

#### ■ MA23

North Bldg 131A

#### Asset Pricing and Portfolio Theory

Sponsored: Finance

Sponsored Session

Chair: Chanaka Edirisinghe, Rensselaer Polytechnic Institute, Troy, NY, 12180-3590, United States

##### 1 - On New Approaches to Modelling and Trading at the Transaction-level Time Scale

James Primbs, California State University Fullerton, 800 N. State College Blvd., Fullerton, CA, 92831, United States, B. Ross Barmish, Sean Warnick

This talk describes our recent research on modelling and trading at a transaction-level time scale. In particular, we utilize ITCH data, which allows for use of order message data to reconstruct the so-called NASDAQ Limit Order Book (LOB). Within this context, we describe numerical experiments aimed at validating our models and evaluating the efficacy of our new high-frequency trading algorithms under development. This talk also includes suggestions for future research motivated by the results of our simulations.

##### 2 - Robo-advising as a Human-Machine Interaction System

Agostino Capponi, Columbia University, 500 W. 120th Street, New York, NY, 10027, United States

The advent of robo-advising has led to an increased interest in applying artificially intelligent agents to the field of portfolio management. Central to all human-machine interactions is the value alignment problem: ensure that an autonomous agent acts according to the human clients that it serves. We introduce a framework to quantify the value of human-machine interaction in a dynamic mean-variance framework. We show that the human-machine tandem exhibits superior performance over traditional robo-advisors.

##### 3 - Portfolio Theory of Three Tales: Risk-adjusted Returns, Liquidity, and Leverage

Chanaka Edirisinghe, Rensselaer Polytechnic Institute, Lally School of Management, Pittsburgh 2118, Troy, NY, 12180-3590, United States, Jingnan Chen, Jaehwan Jeong

Under liquidity costs, we show analytically the Sharpe-maximizing unlevered portfolio is no longer a tangency portfolio, and proportionate-leveraging is not an optimal strategy. As return targets increase, the required minimum portfolio-leverage increases at an increasing-rate, while the Sharpe-Leverage frontiers are progressively-dominated. Empirical analysis verifies our analytical findings, which also shows that ignoring liquidity impact can lead to severe portfolio under-performance.

##### 4 - Optimal Portfolio Deleveraging under Liquidity Costs and Margin Restrictions

Jaehwan Jeong, Assistant Professor, Radford University, Department of Management, P.O. Box 6954, Radford, VA, 24142, United States, Chanaka Edirisinghe

We develop a portfolio deleveraging model under margin restrictions, where trading impacts asset prices. The model objective and constraints are non-convex separable quadratic functions; hence, it is extremely difficult to solve. We develop a new dual-cutting plane technique for solution and test it with leveraged portfolios of ETF assets. Solution efficacy and sensitivity results are reported on leverage and margin limits.

#### ■ MA24

North Bldg 131B

#### User Behavior in Online Marketplaces and Platforms

Sponsored: EBusiness

Sponsored Session

Chair: Yingjie Zhang, Pittsburgh, PA, 15206, United States

##### 1 - Machine Prediction for Better Investment Decision on P2P Platform

Runshan Fu, Carnegie Mellon University, 4800 Forbes Ave., Pittsburgh, PA, 15213, United States, Yan Huang, Param Vir Singh

Two major claimed advantages of P2P lending over traditional banks are 1) funding opportunity for borrowers unqualified for traditional bank loans due to their unattractive credit profiles, and 2) steady and attractive return on investment for lenders. In practice, however, P2P lending platforms often find it difficult to deliver both promises. In this paper, we show that we can achieve both higher return on investment for lenders and more opportunities for borrowers at the same time, by leveraging the predictive power of machine learning techniques. We also demonstrate that while machine learning can be powerful in prediction, realizing its value requires carefully designed economic framework.

##### 2 - Privacy Concerns and Social Recognition Trade Off- Two Natural Experiments on the Role of Online Identity in Crowdfunding

Alvin Zuyin Zheng, 5555 Wissahickon Ave, Philadelphia, PA, 19144, United States, Ohad Barzilay, Paul Pavlou

While online identity has been shown to have significant economic outcomes in online marketplace, disclosure of online identity may cause privacy concerns since it tends to persist across transactions and interactions and thus can carry their own reputation. In this study, we explore the effect of online identity on backers' contribution behavior in crowdfunding by leveraging two natural experiments happened on Kickstarter. Specifically, we are interested two questions: 1) What's the effect of online identity on backer's contribution in crowdfunding? 2) How does this effect differ across different backers (large vs. small)?

##### 3 - Home Bias in Online Employment

Chen Liang, Yili Hong, Bin Gu

We study the nature of home bias in online employment, wherein employers prefer workers hailing from the same countries. Using a large-scale dataset from a major online labor market containing employers' consideration sets and selection of workers, we first estimate home bias in online employment. We disentangle two types of home bias, i.e., statistical and taste-based home bias, using a quasi-natural experiment wherein the platform introduces a monitoring system for employers to observe workers' effort in time-based projects. After matching comparable fixed-price projects as a control group, our DID estimations indicate that home bias is primarily driven by statistical discrimination.

##### 4 - Does Interaction with Promoted Content Help or Hurt Publishers' Readership

Xiaoli Yang, Boston University Questrom School of Business, Boston, MA, 02215, United States, Nachiketa Sahoo

We investigate how interactions with promoted content affect users' tendency to revisit the publisher afterwards. Using a public dataset on users' interactions with promoted content during their visits to multiple publishers, we found that after engaging with promoted content users were 2% more likely to return in a future session to the publisher hosting the links to promoted content. This suggests that interactions with promoted content might have a positive effect on user experience on the publisher's site.

##### 5 - When an Event Comes: A Empirical Analysis on Taxi and Sharing-economy Drivers' Responding Behavior

Yingjie Zhang, CMU, Pittsburgh, PA, 15206, United States

This paper aims to explore the links between users' physical and digital behavior within the social-cyber-physical systems. Specifically, I propose to compare the effects of different types of city events on taxi and sharing-economy drivers. I conduct the study on New York City, using a large-scale trip data of both taxis and for-hire vehicles. From the perspective of city planners, the understanding of responding behavior of drivers, as well as the traffic/demand flows, will allow us to better design countermeasures when an emergency event happens.



## ■ MA25

North Bldg 131C

**Machine Learning in Service**

Sponsored: Service Science

Sponsored Session

Chair: Ashish Gupta, IIM Rohtak, MDU Campus, Rohtak, 124001, India

**1 - Deep Reinforcement Learning and Transfer Learning for Taxi Driver Dispatching**

Zhiwei Qin, DiDi Research America, 450 National Ave, Mountain View, CA, 94043, United States, Zhaodong Wang, Xiaocheng Tang, Jieping Ye, Hongtu Zhu

Deep reinforcement learning has achieved many successes in solving different types of sequential decision problems. In this work, we propose learning solutions based on deep Q-networks to optimize the dispatching policy for taxi drivers on the DiDi ride-sharing platform. We construct the evaluation environment using real-world spatio-temporal trips data and train dispatching agents for this challenging decision task. Due to problem diversity across different cities, transfer learning is brought in to help increase the learning adaptability and efficiency. We empirically evaluate the performance of our dispatching algorithm and show the benefits of knowledge transfer in the spatial domain.

**2 - Modeling Human-robot Collaboration in a Dynamic Workspace as a Markov Decision Process**

Henry I. Ibekwe, GreenBerry Robotics, 2245 Texas Drive, Suite 300, Sugarland, TX, 77479, United States

We present a method for modeling and evaluating the performance of human-robot collaboration for well-defined material handling tasks in a dynamic workspace. Collaborative Robots involves the use of robots to perform tasks alongside humans with the goal of increasing efficiency of the desired task. We model the robot decision-making process as a Markov Decision Process (MDP) where actions executed by the robot are dependent on both the state of the system and the actions performed by the human. An efficient policy for the Markov Decision Process is solved using a dynamic programming algorithm and the policy is implemented for the robot collaborating with a human in a simulated and real environment.

**3 - Operational Improvements in Healthcare using Blockchain**

Sanjeev K. Bordoloi, University of St. Thomas, Opus College of Business, 1000 LaSalle Avenue, TMH 443, Minneapolis, MN, 55403, United States, Sathiyavani Chandran

Blockchain is a decentralized protocol that combines transparency, immutability, and consensus properties to enable secure, pseudo-anonymous transactions. Many healthcare organizations are currently experimenting with Blockchain technology, and its use is expected to grow rapidly. We explore how Blockchain can be used in healthcare for more effective operations such as saving time, reducing cost, reducing risk and increasing trust among stakeholders.

**4 - Recent Approaches to Creating and Analyzing Big Data in Technology Management and Commercialization**

Clovie Hamilton, Assistant Professor of Management, Winthrop University, 310 Thurmond Building, Rock Hill, SC, 29733, United States

This is a study of three (3) technological advances related to Big Data: web scraping, natural language processing and machine learning. This research identifies ways in which these advances can become more relevant and useful to empirical researchers in the field of technology and innovation management. This research provides a brief look at some applications of these advances in research studies, and engenders a broader discussion around the relevance and impact of these advances to research in technology and innovation management. In particular, making use of these advances in empirical research related to technology commercialization was researched and is discussed.

**5 - Identifying Indicators of Blockchain Adoption**

Ashish Gupta, Associate Professor of Analytics, Auburn University, 417 Lowder Hall, 405 West Magnolia Ave., Auburn, AL, 36830, United States, Alireza Farnoush, Dolatsara Ahady Hamidreza, David Paradice

In this study, we use analytics approaches for understanding the characteristics of companies that have the intention to adopt Blockchain technology. We describe the data acquisition process for identifying companies that have intent to adopt. Subsequently, we use financial indicators of the companies and biographical information of the board members to develop our insights.

## ■ MA26

North Bldg 132A

**CRM**

Sponsored: Service Science

Sponsored Session

Chair: Daniel Ringbeck, WHU - Otto Beisheim School of Management, WHU, Vallendar, 1, Georgia

**1 - Predictive and Prescriptive Frameworks Leveraging Customer Lifetime Value**

Pallav Routh, The University of Texas at San Antonio, San Antonio, TX, United States, Arkajyoti Roy, Jeff Meyer

The success of deterministic customer relationship management tools, such as the recency, frequency, and monetary model, is limited amid randomness in customer transactions and future uncertainties in customer churn. We develop a predictive customer lifetime value model under a competing risk framework that overcomes such limitations. Furthermore, we present a prescriptive resource allocation model for marketing campaigns to target high-valued customers with high-risk of churn. The models are evaluated on a membership-based firm in the hospitality industry.

**2 - A Bayesian Network Approach for Predicting Customer Churn**

Yugang Yu, University of Science &amp; Technology of China, 96 JinZhai Road, Hefei, China, Huan Yu, Libo Li

Customer churn prediction is an important business research question for companies to identify potential customer loss. This paper is motivated by a consulting experience with a telecom service provider who try to predict customer churn of different communication operators and channels. The main challenges are the high dimensionality and imbalanced datasets. We develop a novel model which combines a lasso logistic regression for the binary outcome of whether the customers being loyal, with a truncated model of Bayesian network for disloyal customers. Using data from this service provider, our proposed method has a better prediction results compared with other benchmark models.

**3 - Organizing Online Crowds for Value Co-creation**

Zhiyi Wang, National University of Singapore, 15 Computing Drive, COM2-01-02, Singapore, 117418, Singapore, Jungpil Hahn

Crowdsourcing has widely been used as a strategy for sourcing ideas and efforts to facilitate innovation and new product development through Information Technology. However, it is challenging for firms to effectively organize online crowds for innovation and value co-creation. In this study, we investigate an online new product invention community and understand what types of crowds are more important to value co-creation process. Our empirical analysis with data mining and econometric modeling identified important types of contributors in the crowd and their influences on innovation outcomes.

**4 - Multi-focal Lead Scoring for Predictive Modeling in Business-to-business Market**

Jingyuan Yang, George Mason University, Fairfax, VA, United States

An important aspect of customer acquisition in B2B marketing is lead prospecting which guides the business to select the right leads to pursue. While the current practice often selects leads with ad-hoc basis or pure managerial intuitions, a more systematic and data-driven approach is needed to improve the quality of lead selection by quantifying a specific lead's tendency to become a customer. To this end, we introduce a multi-focal predictive lead scoring model which can improve the performance of predictive lead scoring. Specifically, leads are first divided into several focal segments. Then, a logistic regression scoring model is learned for each segment with multi-task learning technique.

**5 - Proactive Retention Management in Retailing Identifying Predicting and Preventing Partial Defection**

Daniel Ringbeck, WHU-Otto Beisheim School of Management, Vallendar, Germany, Dmitry Smirnov, Arnd H. Huchzermeier

Maintaining strong customer relationships is a top priority for retailers. We develop a framework for proactive retention management based on data from a German hypermarket chain. We propose a novel definition of partial defection in noncontractual settings, demonstrate how to forecast the likelihood of defection of individual customers, and formulate a retention campaign optimization model.

## ■ MA27

North Bldg 132B

### Analytics Pedagogy

Sponsored: Education (INFORMED)

Sponsored Session

Chair: Matthew D. Dean, University of Southern Maine, Portland, ME, 04104, United States

#### 1 - Concurrent Undergraduate and Graduate Analytics Program Development Lessons Learned

Stephen Hill, University of North Carolina-Wilmington, 601 South College Road, Wilmington, NC, 28403-5611, United States

Many universities have developed or are developing analytics programs. In this presentation, we will discuss the challenges associated with the simultaneous development of graduate and undergraduate analytics programs. We will share lessons learned and opportunities for improvement.

#### 2 - Teaching Analytics Methods with Jupyter Notebooks and Python

Nickolas K. Freeman, University of Alabama, 14485 Griffin St, Tuscaloosa, AL, 35405, United States

This talk will discuss the use of Jupyter notebooks and the Python programming language for the delivery of analytics content in a classroom setting. Jupyter notebooks are capable of combining rich text elements with executable code, allowing students to execute and visualize analyses in real-time. A simple demonstration will illustrate how the technology may be used to facilitate the presentation of advanced analytics methods. Lessons learned from a recent course based on the technology will also be discussed.

#### 3 - Using the Learning Assistant Model in an Undergraduate Business Analytics Course

Matthew D. Dean, University of Southern Maine, School of Business, 113 Luther Bonney Hall, Portland, ME, 04104, United States

We report the results of the first known implementation of the Learning Assistant Model in a business analytics course (or any business-related course). This pedagogical technique shows promise in helping students master the material better than those who took the course in a traditional lecture-based learning environment. Students' perceptions of the Learning Assistant Model learning environment also improved from the beginning of the semester to the end.

#### 4 - Teaching Experiences of an Elective Operations Research Course in a Business School

Narasimhan Ravichandran, Professor, Indian Institute of Management Ahmadabad, Wing 2 D, Vastrapur, Ahmedabad, 380015, India

I have been teaching a case based course on the applications of OR as an elective in the MBA program at IIMA. Given the changed profile of the participants and the job market compulsions there are some real challenges in teaching this course. In the last three editions we have deployed some innovative methods to deal with the challenges. These ideas are presented in this talk and I explore the options for the future editions of the course.

#### 5 - Lecture Based Tutoring: A New Active Learning Teaching Technique

Todd W. Easton, Kansas State University, 2037 Durland Hall, Manhattan, KS, 66506, United States

This talk describes a new active learning teaching technique called lecture based tutoring. The premise of lecture based tutoring is to tutor students during lectures. The teacher calls a student by name and asks a question. If the student answers poorly, then the student is tutored to the correct answer. Between 20 and 50 such questions are asked each class period and all students participate at least once during a given week. The presentation will demonstrate the method and discuss the statistically significant improvement in both student learning and teacher evaluations. Attendees should leave with sufficient knowledge to attempt this new teaching style.

## ■ MA28

North Bldg 221A

### Maximizing Railway Network Capacity

Sponsored: Railway Applications

Sponsored Session

Chair: Carl D. Van Dyke, TransNetOpt, West Windsor, NJ, 08550, United States

#### 1 - Rethinking Train Scheduling to Improve Network Capacity Management

Carl D. Van Dyke, TransNetOpt, 6 Snowbird Court, West Windsor, NJ, 08550, United States

N.A. Railroads have traditionally scheduled trains with little respect to their interactions with each other. This is particularly true for unit trains and ad hoc trains. To increase network capacity, train performance predictability, and general network fluidity, railroads should change their approach to tactical train scheduling to take into account these interactions. Adding dispatch optimizers is not enough as a metering process is required to ensure that the plan is achievable and the number of trains the dispatcher is to handle will result in reliable operations.

#### 2 - Interaction Between Yard and Mainline Capacity in Railway Network Performance

Tyler Dick, U. of Illinois at Urbana-Champaign, 1241 Newmark Lab MC-250, 205 N. Mathews Avenue, Urbana, IL, 61801, United States

Mainline, yard and terminal performance all contribute to the quality of railway service. Mainlines and yards are symbiotic; a disruption to one operation quickly manifests in reduced performance of the other. Although routinely observed, there has been little academic study of the capacity interactions between mainlines and yards. This presentation provides a high-level overview of the "network efficiency cycle linking mainline and yard performance, and research on the capacity impact of propagating schedule flexibility from yard-to-yard over connecting mainlines.

#### 3 - Increasing Network Capacity through Use of Dynamic Car Scheduling

Clark Cheng, Sr. Director Operations Res & Chief Data Scientist, Norfolk Southern Corporation, 1200 Peachtree Street NE, Mail Stop 171, Atlanta, GA, 30309, United States, Edward Lin, Gunnar Feldmann

Car scheduling is the key operating system for freight railroads to classify railcars and generate trip plans. With dynamic car scheduling, the classification and trip plan for a shipment may vary in order to maximize capacity utilization while improve customer service. In this presentation, we will describe a dynamic car scheduling model developed at Norfolk Southern and how it can improve capacity utilization, operations efficiency, and customer service.

#### 4 - Impact of Improved Maintenance Programs on Railroad Capacity

David T. Hunt, Oliver Wyman, One University Square, Suite 100, Princeton, NJ, 08540, United States

Railroads have progressed their maintenance practices from curative (fix it when it breaks), to systematic (fix it at predetermined intervals), to condition based (fix it based on inspections), and are now working on predictive approaches. This not only leads to safer operations and improved customer service, but has additional benefits in improved rail capacity. This presentation explores how improvements in rail maintenance have impacted capacity, and the corresponding economic consequences.

## ■ MA29

North Bldg 221B

### Joint Session TSL/Practice Curated: Game-theoretic Applications in Urban Transport

Sponsored: TSL/Urban Transportation

Sponsored Session

Chair: Joseph Y. J. Chow, New York University, New York, NY, 10012, United States

#### 1 - Highway Infrastructure Protection Against Sea Level Rise: Game Theoretical Approaches

ILIA Papakonstantinou, NYU, Brooklyn, NY, 11209, United States

This research investigates the differences between game theoretical approaches among decision makers protecting their infrastructure against sea level rise. We take into account the hydrodynamic interactions, transportation system adaptation to inundations due to sea level rise, and budget constraints. Both competitive and cooperative games are considered, where each decision maker aims to minimize traffic delays within its territory caused by the network disruptions due to sea level rise. A case study of the San Francisco Bay area for 0.5m sea level rise is used. The results of different games are compared for a range of budgeting scenarios.

#### 2 - A Many-to-many Auction-based Multimodal Network Assignment Game

Theodoros P. Pantelidis, New York University, Brooklyn, NY, United States

Urban transportation networks are multi-dimensional complex systems that serve large numbers of travelers every day. These complex multimodal systems can be considered as multiple smaller networks which are privately owned by transit operators. When considering pricing and capacity decisions, operators take into account only volume flows in their own network and fail to capture the effects of multimodal trips. In this study, we propose an auction-based game theoretic approach, where travelers act as buyers and network edges as market products that belong to a set of sellers, in order to find the optimal allocation that maximizes joint profits.

### 3 - Modeling On-demand Mobility Service: Competition, Surge Pricing, and Subsidy

Xinwu Qian, Purdue University, 3326 Putnam Street,  
West Lafayette, IN, 47906, United States, Satish Ukkusuri

The study presents the mathematical model for the competition among stakeholders, riders, and drivers in the market of on-demand mobility service. We consider that the stakeholders propose the surge pricing and subsidy policies to maximize their revenue, riders decide whether or not make the trip based on the perceived travel cost, and the drivers decide whether they will leave/enter the market and the location to pick up riders based on their perceived utility. Our results indicate that market efficiency depends on how drivers value their lost for leaving the market. We also observe that subsidizing occupied and vacant trips are important as a regulation to drivers' selfish behavior.

### 4 - Modeling Competition of Intermodal Infrastructure Investors Factoring Their Heterogeneity and Maritime Carrier Behavior

Irina Benedyk, Purdue University, 2411 Neil Armstrong Drive,  
# 2A, West Lafayette, IN, 47906, United States, Srinivas Peeta

This study develops a game theoretical framework that allows one-to-many relationship between investors and intermodal ports, and factors impacts of maritime carrier competing behavior, and investor heterogeneity (defined as a number of intermodal ports under their control) on the investment decision-making process. A solution algorithm is developed to identify and analyze the Nash equilibrium and demonstrate its applicability using the case study of the Northeast U.S. intermodal ports. The study findings can be used by the public sector to evaluate impacts of policies and incentives on intermodal infrastructure development.

## ■ MA30

North Bldg 221C

### Emerging Urban Facilities and Logistics

Sponsored: TSL/Facility Logistics

Sponsored Session

Chair: Wei Qi, McGill University, McGill University, Montreal, QC, H3A 1G5, Canada

Co-Chair: Guangrui Ma, Tianjin University, THong Kong, 300072, China

### 1 - Congestion Reduction through Efficient Empty Container Movement

Santiago Carvajal, University of Southern California, Los Angeles, CA, 90007, United States

My presentation will revisit the Empty Container Problem using double container trucks. This research was started by a METRANS project with the Ports of Los Angeles and Long Beach in an attempt to reduce congestion at the ports. The problem is divide into two sub-problems, a container assignment problem and a vehicle routing problem. In this presentation I will present my methodology for solving the problem and my mathematical models, as well as presenting some general results as well as results from the Ports of Los Angeles and Long Beach.

### 2 - Dynamic Electrical Vehicle Sharing System Design

Xin Wang, University of Wisconsin-Madison, 8916 Red Beryl Drive, Middleton, WI, 53562-4278, United States, Yikang Hua, Dongfang Zhao, Xiaopeng Li

Electrical vehicle (EV) sharing advances the green city development, however it faces various challenges in practical operations such as infrastructure deployment and vehicle relocation. We build a multi-stage stochastic model aiming to reduce cost and customer queueing for EV sharing system. We provide an algorithm which combines Lagrangian relaxation and Benders Decomposition to solve the model. Our model helps design EV sharing infrastructure under uncertain demand arrival together with the daily dispatch and relocation decisions.

### 3 - Inventory Repositioning in On-demand Product Rental Networks

Saif Benjaafar, University of Minnesota, 111 Church Street SE, Department of Industrial and Systems Engr, Minneapolis, MN, 55419, United States, Xiaobo Li

We consider a product rental network with a fixed number of rental units distributed across multiple locations. Customers can pick a unit at one location and return it to another. Both demand for rentals and rental durations are random. To improve the matching of supply and demand, units are periodically repositioned. We formulate the inventory repositioning problem as Markov decision process and characterize the optimal policy. We also describe an efficient heuristic.

### 4 - Shared Autonomous Electric Vehicles for Strengthening Future Urban Microgrids

Wei Qi, McGill University, 1001 Sherbrooke Street West, Montreal, QC, H3A 1G5, Canada, Mengyi Sha, Shanling Li, Hong Chi

We envision the prospect where shared autonomous electric vehicles (SAEVs) will reinforce future urban electricity infrastructure in the form of solar-powered microgrids. We integrate cross-disciplinary modelling of transport and power systems with optimization to investigate the potential of SAEVs for improving the self-sufficiency and resilience of urban microgrids. Our model prescribes optimal citywide SAEV fleet operations of ride-sharing, repositioning, charging and discharging amidst various urban heterogeneities. Our findings highlight the value of centralized dispatchability of SAEVs.

## ■ MA31

North Bldg 222A

### Shared Mobility Optimization for Public Transportation

Sponsored: TSL/Intelligent Transportation Systems (ITS)

Sponsored Session

Chair: Jiangtao Liu, Arizona State University, Tempe, AZ, 85282, United States

Co-Chair: Xuesong Zhou, Arizona State University, Tempe, AZ, 85281, United States

### 1 - Designing Dynamic and Personalized Incentives in Sustainable Ridesharing Systems

Yanshuo Sun, Florida State University, Tallahassee, FL, 20742, United States

This study considers the option of influencing ridesharing participants' original travel schedules by applying monetary incentives. In this system, drivers can opt for an incentive program where a driver specifies how much she/he expects to be compensated if the earliest departure time at the origin is shifted to be earlier than the originally scheduled time. The level of behavioral realism is thus improved by considering the possibility of drivers' misrepresenting their required compensations to modify their travel schedules. The contribution of this study is to propose a mechanism which ensures only "efficient drivers are eligible for incentives given an incentive budget limit.

### 2 - Accessibility with Time and Resource Constraints

Monireh Mahmoudi, Assistant Professor, Michigan State University, East Lansing, MI, 48824, United States, Ying Song, Harvey Miller, Xuesong Zhou

A common accessibility measure in transportation science is the space-time prisms (STPs) and the network-time prisms (NTPs). STPs and NTPs focus on time as the scarce resource limiting accessibility. However, other resource constraints can constrain space-time accessibility, such as limits or "budgets for energy, emissions, or monetary expenses. This research extends NTPs to include other resource constraints in addition to time. We conceptualize resource hyper-prisms (RHPs) as a constrained optimization problem and develop a resource-dependent time-dependent forward and backward dynamic programming to determine the boundaries of a RHP given time and other resource budgets.

### 3 - Integrated Train Timetabling and Locomotive Assignment

Zhou Xu, The Hong Kong Polytechnic University, Hong Kong, China, Xiaoming Xu, Chung-Lun Li

This work focuses on modeling and solving an integrated train timetabling and locomotive assignment problem. To solve this integrated problem, we first construct a three-dimensional state-space-time network in which a state is used to indicate which train a locomotive is serving. We then formulate the problem as a minimum cost multi-commodity network flow problem with incompatible arcs and integer flow restrictions, and present a Lagrangian relaxation heuristic for solving problem.

### 4 - Dynamic Dial-a-ride and Pricing with Look Ahead for Competitive On-demand Mobility Systems

Hamid Sayarshad, Cornell University, Ithaca, NY, 14850, United States, H. Oliver Gao

We propose a competitive on-demand mobility model using a multi-server queue system under infinite-horizon look-ahead. The proposed approach includes a novel dynamic optimization algorithm which employs a Markov decision process (MDP) and provides opportunities to revolutionize conventional transit services that are plagued by high cost, low ridership, and general inefficiency, particularly in disadvantaged communities and low-income areas. We develop a dynamic pricing scheme that utilizes a balking rule that incorporates socially efficient level and the revenue-maximizing price, and an equilibrium-joining threshold obtained by imposing a toll on the customers who join the system.



## ■ MA32

North Bldg 222B

**Alternative-Fuel Vehicles for Sustainable Transportation**

Sponsored: TSL/Freight Transportation &amp; Logistics

Sponsored Session

Chair: Mesut Yavuz, University of Alabama, Tusc, AL, 35487, United States

Co-Chair: Isil Koyuncu, The University of Alabama, Tuscaloosa, AL, 35406, United States

**1 - Optimizing Placement of Electric Vehicle Charging Stations and Incentives to Combat Overstaying**

Ragavendran Gopalakrishnan, Postdoctoral Associate, Cornell University, Ithaca, NY, United States, Arpita Biswas, Partha Dutta

In this two-part talk, we first discuss optimizing placement of Electric Vehicle (EV) charging stations with both budget and coverage constraints, by introducing an iterative heuristic to solve a mixed packing-and-covering problem by alternately invoking knapsack and set-cover algorithms. Next, with increasing adoption of EVs, overstaying after active charging lowers utilization, and warrants imposing penalties. Higher penalties could be unacceptable to risk-averse users due to uncertain parking durations, leading to decreased utilization (and revenue). Our solution, validated on London charging data, increases both utilization and revenue while significantly reducing overstaying.

**2 - Charging Station Network Design for Electrified Vehicles in Urban Communities**

Seyed Sajjad Fazeli, Wayne State University, Detroit, MI, United States, Saravanan Venkatachalam, Ratna Babu Chinnam, Alper E. Murat

The societal benefits of large-scale adoption of EVs cannot be realized without the adequate deployment of accessible charging stations due to mutual dependence of EV sales and public infrastructure deployment. Such infrastructure deployment also presents some unique opportunities for promoting livability within communities. In this research, we develop models and methods to improve community's access to the EV charging stations. A choice modeling approach embedded into two-stage stochastic programming model is proposed to determine the optimal network of charging stations including type, capacity, and location of electric charging stations based on EV drivers preference.

**3 - Financial Analysis of Electric Vehicle Fast Charging: A Case Study in San Diego California**

Eleftheria Kontou, National Renewable Energy Laboratory, 15013 Denver West Parkway, Golden, CO, 80401, United States

The objective of this study is financial analysis of electric vehicle (EV) fast charging stations. We focus on a case study in San Diego CA and we utilize three models to simulate chargers utilization over the planning horizon of 2018 to 2025, analyze operational costs of electricity under an EV pricing scheme, and estimate profitability indices and net present values for several scenarios of 125 and 400kW plugs stations. We explore the impact of the station's number of plugs, power level and power-sharing, energy storage sizes, and photovoltaic array collocation on the financial viability of such EV fast charging stations providers.

**4 - Green Inventory Routing Problem for Perishable Products**

Gokce Palak, Shenandoah University, 1460 University Dr., Winchester, VA, 22601, United States

We consider a multi-period multi-vehicle green inventory routing problem for perishable products. Through a numeric study, we analyze the impacts of age-dependent perishability, carbon emissions, and a heterogeneous fleet on inventory management and routing decisions.

## ■ MA33

North Bldg 222C

**Autonomous Vehicles: Service Design, Management, and Control**

Sponsored: TSL/Intelligent Transportation Systems (ITS)

Sponsored Session

Chair: Rongsheng Chen, University of Minnesota, Minneapolis, MN, United States

**1 - An Optimization Approach for Vehicle Re-balancing in a Mobility-on-demand System**

Liu Xu, University of Maryland-College Park, 1173 Glenn L. Martin Hall, College Park, MD, 20742, United States, Xinlei Zhang, Ali Haghani

With Mobility-on-Demand system serves as the first-and-last-mile solution, the public transit can greatly extend its coverage, thereby alleviating congestion on the roads. In the context of such a hybrid system, due to the imbalanced nature between customer pick-up and drop-off, rebalancing the vehicles is necessary to ensure adequate performance. This study proposes an approximate dynamical programming solution to optimally making the vehicle relocation decisions, aiming at minimizing the number of rebalanced vehicles. Extensive simulation results show that the proposed strategy can significantly reduce the customer walk-aways and allow the system to operate with a smaller fleet size.

**2 - Evaluating Spatial Pricing in Ride Sourcing Systems a Graph Fused Lasso Denoising Approach**

Natalia Zuniga-Garcia, Graduate Research Assistance, University of Texas at Austin, Department of Civil, Architectural and Environmental Engineering, 301 E. Dean Keeton St. Stop C1761, Austin, TX 78712, United States., Austin, TX, 78712, United States, Mauricio Garcia-Tec, James G. Scott, Natalia Ruiz-Juri, Randy B. Machemehl

This study explores the spatial pricing discrimination of ride-sourcing trips using empirical data from over 1 million rides in Austin, Texas. We implement the graph-fused lasso (GFL) technique as a total variation denoising method. GFL globally smooths anisotropic discrete data while maintaining local adaptivity. GFL smoothing is posed as a convex optimization problem, and we solve it using a novel flexible and scalable algorithm with high computational efficiency. Our results include a temporal and spatial exploration of different ride-sourcing operational and productivity variables in Austin.

**3 - Dynamic Traffic Assignment of Autonomous Mobility On-demand**

Rongsheng Chen, University of Minnesota, Minneapolis, MN, 55455, United States, Michael W. Levin

This study explores the traffic conditions of a city road network with many travelers served by autonomous mobility-on-demand. The focus is to model the effect of rebalancing traffic which is caused by the unbalanced distribution of travelers and vehicles. A modified dynamic traffic assignment which includes car-sharing trip chains is used to find user equilibrium behavior. A linear program with flow conservation constraints is used to calculate the number of rebalancing trips with minimum total travel cost and to generate the dispatch strategy.

## ■ MA34

North Bldg 223

**8:00 - 8:45 JMP. A division of SAS /8:45 - 9:30 Optimization Direct**

Vendor Demo Session

**1 - Analyzing Unstructured Text Data with the JMP Pro 14 Text Explorer**

Mia L. Stephens, SAS Institute Inc, P.O. Box 290, York Harbor, ME, 03911, United States

In the era of big data, a majority of the data captured by organizations is unstructured. Much of this unstructured data is in the form of text - from customer feedback, survey results, emails and texts, web reports, social media and other channels. Analyzing this text-based information is particularly challenging, but the new Text Explorer platform in JMP 14 makes it easy. This platform provides an efficient and interactive tool for analyzing unstructured text data, allowing us to easily extract information and transform unstructured text data into structured information. In this session, we'll use case studies to demonstrate how to use the JMP Text Explorer platform to analyze unstructured text data. We'll use a word cloud to visualize word frequency, use latent class analysis to cluster words, and apply other tools to understand underlying themes in unstructured text data. We'll also see how to create a document term matrix (DTM), and will use the resulting structured data in predictive modeling.

**2 - A DOCplex and ODH|Cplex Python Primer**

Robert Ashford, Optimization Direct, Harrington Park, NJ, United States

This short tutorial shows participants how to build a basic model using the DOCplex API in python. This session includes setting the python environment, reading data from a csv or spreadsheet, creating variables, objective functions, constraints, solving the model, and returning the results. Additionally this session points the participants to further reading so that they may expand their capabilities. Furthermore we will present the brand new ODH|Cplex API for python, which improves solution times for large models.

## ■ MA35

North Bldg 224A

**AAS Best Student Presentation Competition I**

Sponsored: Aviation Applications

Sponsored Session

Chair: Susan Hotle, Virginia Polytechnic Institute and State University.

**1 - Impact of Payload Amount on Battery Consumption Rate in a Delivery Application of Drones**

Maryam Torabbeigi, University of Houston, Houston, TX, United States

The drone battery charge limitation is an important factor in drone scheduling in order not to run out of battery during the flight. This study investigates the relationship between battery consumption rate (BCR) and the payload amount, and also the impact of payload amount (customer's demand) on the drone scheduling. The collected data verifies a linear relationship between BCR and the payload amount. A routing problem is proposed for the drone scheduling. The model determines the number of drones, their path, the assigned customers, and the battery charge at each flight segment. The results show the impact of including BCR in the scheduling.

**2 - Airline Passenger Route Share Forecast**

Xufang Zheng, Iowa State University, 537 Bissell Road #2362, Ames, IA, 50010, United States

Airline passenger route share(directShare) is the ratio of direct passengers to total passengers on O&D level. It is an important feature of passenger flow distribution. DirectShare is an O&D specific feature, which is highly correlated with quarterly lag. Various supervised learning methods are carefully explored. The best model is gradient boosting machine(GBM), which has better prediction performance than FAA TAF-M directShareforecast model. Category based learning is newly proposed, which provides better prediction performance than GBM. The C-basedapTC model is the best category based learning model, which can provide a long term directShare forecast with less fluctuations.

**3 - Autonomous On-Demand Free Flight Operations in Urban Air Mobility Using Monte Carlo Tree Search**

Xuxi Yang, Iowa State University, Howe Hall, 537 Bissell Rd, Ames, IA, 50011, United States

Vertical takeoff and landing (VTOL) aircraft for on-demand air taxi will bring fundamental changes to daily commutes. NASA, Uber, and Airbus have been exploring the exciting concept of Urban Air Mobility (UAM). In order to enable safe and efficient autonomous on-demand free flight operations in this UAM concept, a computational guidance algorithm was designed and analyzed with collision avoidance capability. The approach is to formulate this problem as a Markov Decision Process and solve it using Monte Carlo Tree Search. A simplified numerical experiment was created and results show that this algorithm can help aircraft quickly reach the trip destination and avoid conflicts with other aircraft.

**4 - Safe and Efficient Arrival of EVTOLS in On-Demand UAM**

Priyank Pradeep, Iowa State University, 537 Bissell Road, Howe Hall, Ames, IA, 50011, United States

The electric vertical takeoff and landing (eVTOL) aircraft can alleviate ground congestion by utilizing three-dimensional airspace. However, the endurance of Lithium-ion Polymer (Li-Po) batteries imposes constraints on the operational time span. The first part focuses on formulations of a fixed final time multiphase optimal control problem with energy consumption for the eVTOL multirotor and tandem tilt-wing aircraft types. The second part involves a sequencing problem for a mixed fleet of eVTOLs scheduled to land on a vertiport with single landing slot. A sensitivity analysis is performed to see the impact of the fleet mixture and resequencing on the landing completion time.

## ■ MA36

North Bldg 224B

**Joint Session AAS/Practice Curated: Airline Crew Management**

Sponsored: Aviation Applications

Sponsored Session

Chair: Bruno F. Santos, TU Delft, Delft, 2629 HS, Netherlands

**1 - Generating Crew Pairings for Cargo Aviation**

Junhong Guo, University of Michigan, Ann Arbor, MI, United States, Amy Cohn

We consider a variation of the airline crew pairing problem in which we focus on the challenges faced by a cargo carrier with predominantly long-haul international flights. The difference in rules and pairing characteristics relative to domestic passenger aviation (e.g. pairings are typically on the order of 15 days) provide both challenges and opportunities. We present heuristics and optimization-based approaches for improving this process.

**2 - Dynamic Design of Reserve Crew Pairings for Long Haul Airline Crew**

Lennart Scherp, PhD Candidate, Delft University of Technology, Delft, Netherlands, Richard Janssen, Bruno F. Santos

In this work we propose a new reserve crew pairings generation algorithm. A method is used that iteratively selects a set of pairings and evaluates them based on simulations of roster disruptions to obtain the most efficient set of reserve pairings. The goal is to minimize the effects of disruptions on rosters. Results show improvements of about 5% over the current approach used by a large European airline.

**3 - Airline Crew Scheduling with Re-timing and Complex Aircraft Connection Rules**

Fredrik Altenstedt, Optimization Expert, Jeppesen, Odinsgatan 9, G teborg, SE-411 03, Sweden

This presentation considers finding crew trips covering all flights for an airline given that we may adjust the flight times slightly, commonly known as the pairing problem with retiming. The aircraft routes influence the crew rules, shorter connections are allowed if the crew does not change aircraft. Both re-timings and short connections may require extra aircraft. This is normally prevented using plane count constraints, but these only work for simple connection rules. We give an overview of how we maintain aircraft feasibility for more complex rules by generating aircraft consistency constraints dynamically as well as share our experience from using the system with one of our clients.

**4 - Shift Scheduling with Flexible Execution Times and Sequence Dependent Travel**

Pouya Barahimi, Oregon State University, Corvallis, OR, 97331, United States, Hector Vergara

We consider the scheduling problem where each task may require multiple workers with different skills. Tasks have fixed duration and can be executed within a given time window. Travel times between tasks are different. The objective is to maximize the reward gained by executing tasks given a limited team of workers. A branch-and-price algorithm and two heuristics are developed to solve instances. A numerical study assessing the effect of inputs on run-time and quality of the solutions obtained is presented. The problem is presented in the context of the airline industry where ground crew located at an airport perform tasks to get flights ready for departure.

**5 - Modeling Flight Effort in Air Operations Training Programs**

Sergio Rebouas, Technological Institute of Aeronautics, Praa Marechal Eduardo Gomes, 50, Sao Jose dos Campos, Brazil, Talita Alessandra da Silva, Fernando Teixeira Abrah o

The flight effort forecasting in pilot training programs is a challenge for civil and military organizations. The mobilization of material and human resources to support air operations is the main factor of impact in their economic health and administrative efforts. The logistic and operational support contracts are based on this forecast, whose inaccuracy would imply significant financial and administrative consequences. This article describes a method to estimate flight effort based on a pilot's training program, integrating the individual instructions, operational and maintenance constraints and historical data, with the objective of maximizing its accuracy.

## ■ MA37

North Bldg 225A

**Modern Approaches to Stochastic Control**

Sponsored: Applied Probability

Sponsored Session

Chair: Vivek Farias, Massachusetts Institute of Technology, Cambridge, MA, 02139, United States

Co-Chair: Ciamac Cyrus Moallemi, Columbia University, New York, NY, 10027, United States

**1 - Reinforcement Learning in Portfolio Optimization**

Eli Gutin, Massachusetts Institute of Technology, Cambridge, MA, 02139, United States, Vivek Farias, Ciamac Cyrus Moallemi

In this talk we propose a general deep RL, policy-gradient based algorithm for tackling high-dimensional control problems with continuous state and action spaces, and quasi-linear dynamics. We demonstrate state-of-the-art performance on key benchmark problems in dynamic portfolio optimization and algorithmic trading. On some instances we see a provable near-zero optimality gap, compared to existing cutting-edge approaches that achieve around a 5% gap.

## 2 - A Finite Time Analysis of Temporal Difference Learning

Dan Russo, Columbia University, New York, NY, 10027, United States

Temporal difference learning (TD) is a simple iterative algorithm used to estimate the value function corresponding to a given policy in a Markov decision process. Although TD is one of the most widely used algorithms in reinforcement learning, its theoretical analysis has proved challenging and few guarantees on its statistical efficiency are available. In this work, we provide a simple and explicit finite time analysis of temporal difference learning with linear function approximation. Except for a few key insights, our analysis mirrors standard techniques for analyzing stochastic gradient descent algorithms, and therefore inherits the simplicity and elegance of that literature.

## 3 - Ensemble Sampling

Xiuyuan Lu, Stanford University, Stanford, CA, United States, Benjamin Van Roy

Thompson sampling has emerged as an effective heuristic for a broad range of online decision problems. In its basic form, the algorithm requires computing and sampling from a posterior distribution over models, which is tractable only for simple special cases. In this talk, I will give a brief introduction on ensemble sampling, a heuristic that aims to approximate Thompson sampling while maintaining tractability even in the face of complex models such as neural networks. Ensemble sampling dramatically expands on the range of applications for which Thompson sampling is viable. I will talk about recent progress as well as some applications in digital marketing.

## 4 - Thompson Sampling with Information Relaxation Penalties

Seungki Min, Columbia University, New York, NY, United States, Costis Maglaras, Ciamac Cyrus Moallemi

We propose a general framework for improving Thompson sampling by applying penalties. At each decision epoch, instead of choosing the action myopically optimized to the sampled values of the unknown parameters, we incorporate an additional penalty to compensate for the information relaxation that arises assuming that these parameters are known. We illustrate the flexibility and performance of our method with examples.

## ■ MA38

North Bldg 225B

### APS Session Subramanian

Sponsored: Applied Probability

Sponsored Session

Chair: Vijay Subramanian, University of Michigan, Ann Arbor, MI, 48109, United States

## 1 - Mode-suppression: A Simple and Provably Stable Chunk-sharing Algorithm for Peer-to-peer Networks

Srinivas Shakkottai, Texas A&M University, College Station, TX, United States, Vamseedhar Reddyvari, Parimal Parag

The ability of a P2P network to scale up throughput with increasing peer arrival rate depends on the chunk sharing policy. Some policies can result in low frequencies of a chunk, leading to system instability. Recent efforts have focused careful chunk boosting to mitigate this issue. We take a complementary view, and instead recommend preventing sharing of the most frequent chunk(s). We refer to this policy as mode suppression. We prove system stability using Lyapunov techniques, and also show that the total download time under our policy does not depend on peer arrival rate. Finally, we design distributed heuristics, and show numerically that mode suppression outperforms all other policies.

## 2 - On Information State and Sequential Decomposition in Decision Problems with Strategic and Non-strategic Agents

Hamidreza Tavaafoghi, University of California-Berkeley, Berkeley, CA, United States, Ouyang Yi, Demosthenis Teneketzis

We study dynamic multi-agent decision problems with asymmetric information. We propose the notion of sufficient information that provides a compression of agents' private and common information in a mutually consistent manner. We show that restriction to sufficient information-based (SIB) strategies is without loss of generality when agents are not strategic (i.e. teams), and provide a sequential decomposition of dynamic teams over time. When agents are strategic (i.e. games), we show that the class of SIB strategies is closed under the best response map. Consequently, we propose a notion of SIB equilibrium and provide a sequential decomposition of dynamic games over time.

## 3 - On Communication in Multi-agent Reinforcement Learning

Parinaz Nagizadeh, Purdue University, West Lafayette, IN, United States, Maria Gorlatova, Andrew Lan, Mung Chiang, Mung Chiang

We study the role of communication in a multi-agent reinforcement learning problem, where agents aim to learn to coordinate their actions and maximize their rewards through repeated interactions with an unknown, partially observable environment. We assume agents can communicate their partial state observations, and identify two benefits of this information sharing when agents' observation quality is heterogeneous: it facilitates coordination among them, and further enhances the learning rate of both better informed and less informed

agents. We show however that these benefits will depend on the communication timing, in that delayed information sharing may be preferred in certain scenarios.

## 4 - Local Weak Convergence Applied to a Local Preferences Based Random Graph Model

Vijay Subramanian, University of Michigan, 1301 Beal Avenue, #4112 EECS, Ann Arbor, MI, 48109, United States, Mehrdad Moharrami, Mingyan Liu, Rajesh Sundaresan

Random graph models are used to model individual preferences innate to graph construction. Each model proposes a unique construction that covers some properties of real-world networks. We study asymptotics of a new model that uses the self-optimizing behavior of individuals where the cost/benefit of a link factors in its existence: prove the model locally weakly converges to the rooted tree of a branching process, the Erlang Weighted Tree(EWT), and study the EWT. This allows us to study phase transitions to giant components of the graph family when direct and well-studied methods (first-moment and second-moment) do not apply, owing to the dependency structure begot by self-optimization.

## ■ MA39

North Bldg 226A

### Modern Scheduling

Sponsored: Applied Probability

Sponsored Session

Chair: Alan Scheller-Wolf, Tepper School of Business, Tepper School of Business, Pittsburgh, PA, 15213, United States

Co-Chair: Mor Harchol-Balter, Carnegie Mellon University, Pittsburgh, PA, 15213, United States

## 1 - Soap: One Clean Analysis of all Age-based Scheduling

Mor Harchol-Balter, Carnegie Mellon University, 5000 Forbes Avenue, Computer Science Dept, Pittsburgh, PA, 15213, United States, Ziv Scully, Alan Scheller-Wolf

We consider an extremely broad class of  $M/G/1$  scheduling policies called SOAP: Schedule Ordered by Age-based Priority. The SOAP policies include most scheduling policies in the literature as well as an infinite number of variants which have never been analyzed, or maybe not even conceived. SOAP policies range from classic policies, like Class-based-Priority, Foreground-Background (FB), and Shortest-Remaining-Processing-Time (SRPT), to much more complicated scheduling rules, such as the famously complex Gittins index policy and Shortest-Expected-Remaining-Processing-Time (SERPT), which have resisted analysis. We present a universal analysis of response time for all SOAP policies.

## 2 - Shortest Remaining Processing Time for Multiserver Systems

Isaac Grosf, Carnegie Mellon University, Pittsburgh, PA, United States, Mor Harchol-Balter, Ziv Scully

The Shortest Remaining Processing Time (SRPT) scheduling policy and its variants have been extensively studied. While beautiful results are known for single-server SRPT, much less is known for multiserver SRPT. In particular, stochastic analysis of the  $M/G/k$  under multiserver SRPT is entirely open. We give the first stochastic analysis bounding mean response time of the  $M/G/k$  under multiserver SRPT. Using our response time bound, we show that multiserver SRPT has asymptotically optimal mean response time in the heavy-traffic limit. Beyond SRPT, we prove similar response time bounds and optimality results for several other multiserver scheduling policies.

## 3 - Optimal Scheduling and Exact Response Time Analysis for Multistage Jobs

Ziv Scully, Carnegie Mellon University, 5000 Forbes Avenue, GHC 7121, Pittsburgh, PA, 15213, United States, Mor Harchol-Balter, Alan Scheller-Wolf

Scheduling to minimize mean response time of the  $M/G/1$  queue is usually addressed in one of two cases: that of known job sizes, in which SRPT is optimal, and that of unknown job sizes, in which the more complex Gittins index policy is optimal. However, in real systems we often have partial job size information. We introduce a new model of multistage jobs to capture this case. A multistage job has multiple stages of unknown size, but the scheduler always knows which stage is in progress. We give an optimal algorithm for scheduling multistage jobs and exactly analyze its mean response time. As a special case, we obtain a closed-form expression for mean response time of the Gittins index policy.

## 4 - On Optimal Scheduling in Input-queued Switches

Mark S. Squillante, IBM Research, Yorktown Heights, NY, 10598, United States, Yingdong Lu, Siva Theja Maguluri, Tonghoon Suk

We consider issues related to optimal scheduling in input-queued switches, which are widely used in modern computer and communication networks. Theoretical properties are established and computational experiments are presented to demonstrate the benefits of our approach.



## ■ MA40

North Bldg 226B

**Joint Session APS/RMP: Revenue Management and Pricing in Service Systems**

Sponsored: Applied Probability

Sponsored Session

Chair: Yasar Levent Kocaga, Sy Syms School of Business, New York, NY, 10033, United States

**1 - Operational Perils and Benefits of Free Trials in Large Scale Service Systems**

Yasar Levent Kocaga, Sy Syms School of Business, Belfer Hall Room # 403/A, 2495 Amsterdam Ave, New York, NY, 10033, United States, Chihoon Lee

We consider a firm that is serving price and delay sensitive customers and that has the option of offering a free trial service to a new market of customers. We first show that it is optimal for the revenue maximizing firm to operate in the QED heavy traffic regime and provide tractable and accurate expressions for the optimal price and revenue. Then, we use these expressions to identify conditions under which offering free trials is beneficial to the firm.

**2 - Naor's Model with Uncertain Arrival Rates and Heterogeneous Customers**

John Hasenbein, University of Texas-Austin, 1 University Station Stop C2200, Department of Mechanical Engineering, Austin, TX, 78712-0292, United States, Chengcheng Liu

We study Naor's model in which the arrival rate is uncertain and customers are heterogeneous in either their value of service or holding cost per unit time, or both. Even characterizing the stability of such systems is non-trivial. We focus on the case when the queue length is observable to the customers, and allow a social optimizer or revenue maximizer to manage the system.

**3 - Managing Service Systems via Disguised Queues: The Role of Customers' Retaliatory Behavior**

Eren Basar Cil, University of Oregon, 1208 University of Oregon, Lindquist College of Business, Eugene, OR, 97403-1208, United States

This paper studies firms that can partially disguise their waiting lines to influence customer demand. We investigate the impacts of customers' retaliatory behavior on the firm's queue hiding decisions and profits. We show that firms can significantly benefit from disguised queues if customers retaliate to queue disguising tactics whereas any disguised queues hurt firms when they face non-retaliating customers.

**4 - Asymptotic Analysis of Multi Queue Service Systems with Dynamic Customer Choice**

Yichuan Ding, University of British Columbia, University of British Columbia, 6333 Larkin Drive, Vancouver, BC, V6T 1C3, Canada, Mahesh Nagarajan, Zhe Zhang

This paper introduces a multiclass queueing model to study a stochastic service system with multiple servers and dynamic consumer choice. We consider service providers of heterogeneous quality distributed at different locations with heterogeneous customers arriving randomly to the system. An arriving customer chooses a service provider to obtain service. We prove that the fluid limit process has a unique equilibrium, and the diffusion limit process is a reflected multi-dimensional Ornstein-Uhlenbeck process centered at that equilibrium.

## ■ MA41

North Bldg 226C

**Decision Analysis, Game Theory, Big Data, and Disaster Management**

Sponsored: Decision Analysis

Sponsored Session

Chair: Jun Zhuang, University at Buffalo, Buffalo, NY

**1 - Game-theoretic Modeling of Pre-disaster Relocation**

Vicki Bier, University of Wisconsin-Madison, 1513 University Avenue, Room 3234, Madison, WI, 53706, United States, Hongru Du, Yuqun Zhou

This talk uses game theory in conjunction with standard exponential discounting to explore strategies by which governments might encourage pre-disaster relocation by residents living in high-risk areas. We find that offering a subsidy (e.g., a partial buyout) can frequently be effective, if government has a lower discount rate than residents. We also present extensions to our model, exploring the use of a fixed annual benefit after relocation (instead of a one-time subsidy), and hyperbolic instead of exponential discounting.

**2 - Capabilities-based Planning for Emergency Preparedness**

Cameron MacKenzie, Iowa State University, Ames, IA, United States, Rohit Suresh

The Federal Emergency Management Agency's (FEMA) National Preparedness System identifies 32 core capabilities for emergency preparedness. State and local agencies must assess how well their organizations are performing in each of those 32 capabilities. However, measuring these capabilities is very difficult and understanding how these capabilities relate to each other is also very challenging. We apply the principles of value-focused thinking and Bayesian belief networks to help states to conduct capabilities-based planning for emergency preparedness.

**3 - Detection of Fake Social Media Postings Following Soft-target Terror Attacks: A Signal Detection ROC Analysis**

Richard S. John, University of Southern California, Dept of Psychology MC 1061, Los Angeles, CA, 90089-1061, United States, Mengtian Zhao

We investigated the ability of individuals to detect false information from actual posts on social media platforms. In 3 experiments manipulating the base rates for false information and the penalty for incorrect classification, US participants viewed Tweets posted shortly after terrorist attacks on soft targets in the US and Europe, and judged the authenticity of information for each post. Using a signal detection framework, participants performed only slightly better than chance, consistent with previous research on lie detection. Respondents were relatively insensitive to manipulation of base-rates and relative error penalties.

**4 - Analyzing, Modeling, and Detecting the Spread of Misinformation on Social Media during Natural Disasters**

Kyle Hunt, Student, University at Buffalo, Buffalo, NY, 14228, United States, Bairong Wang, Jun Zhuang

Our studies investigate the spread of misinformation on social media through big data analysis and mathematical modeling. We implement techniques such as network analysis, sentiment analysis, predictive modeling, and decision modeling to understand the dissemination features of rumor spreading and rumor debunking information across Twitter's network. Results from data analysis show that official debunks from government accounts were very effective in combating the spread of rumors, which can offer valuable insight on the optimal use of such accounts. Results from current studies will show the attitudes and behaviors of Twitter users during times of rumor spreading on Twitter.

**5 - Prepare or Wait? The Marine Forces Reserve Hurricane Decision Simulator**

Eva D. Regnier, Naval Postgraduate School, 555 Dyer Road, Bldg. 330, Room 287, Monterey, CA, 93943, United States, Cameron MacKenzie

After 2012's Hurricane Ivan, the U.S. Marine Forces Reserve (MFR) asked for help with a challenging decision-whether and when to incur up to \$10M in direct cost to prepare for a hurricane that may or may not affect their operations. We worked with Marines and other local officials to understand and model their decision processes and used data analytics to build a storm-simulation model. The result is an online training tool that the MFR has used since 2016. The simulator lets individual users experience decades' worth of storms in a few hours. In team exercises, MFR reports that the HDS training provides a more realistic experience than hand-generated scenarios used previously.

## ■ MA43

North Bldg 227B

**Energy and Climate II**

Emerging Topic: Energy and Climate

Emerging Topic Session

Chair: Valerie Thomas, Georgia Tech, GA, United States

**1 - Quantification of Technological Uncertainty in Evaluating the Feasibility of Meeting Emission Targets**

Dong Gu Choi, Pohang University of Science and Technology (POSTECH), 77 Chengam-Ro, Nam-Gu, Pohang, Gyeongbuk, 37673, Korea, Republic of, Hansung Kim

Recent studies have considered uncertainty for GHG reductions by using the stochastic programming model for energy systems. The models require values of input parameters in the form of a scenario tree to handle uncertainty. However, only few studies have used quantitative methods to generate scenarios of the future values of technological input parameters. We show that the scenarios of the future values of the technological input parameter for energy system models can also be generated by a quantitative methodology. In addition, we introduce how to quantify the risk for the feasibility of meeting GHG emission targets by incorporating the technological uncertainty.

## 2 - Optimizing the Use of CO2 Bulk Energy Storage for Transmission Deferral

Ramteem Sioshansi, Associate Professor, The Ohio State University, 240 Baker Systems Engineering Building, 1971 Neil Avenue, Columbus, OH, 43210-1271, United States, Jonathan D. Ogland-Hand, Jeffrey M. Bielicki, Ebony S. Nelson, Benjamin M. Adams, Thomas A. Bushcheck, Martin O. Saar

CO<sub>2</sub>-bulk energy storage (CO<sub>2</sub>-BES) can store electricity by compressing and injecting CO<sub>2</sub> into the subsurface. Electricity is discharged by producing geothermally-heated CO<sub>2</sub> and converting that heat into electricity. We investigate the value that CO<sub>2</sub>-BES may have for transmission line deferral when electricity that is generated from a Class 5 wind resource in Wyoming is sold to a high-demand location in California. Results suggest that CO<sub>2</sub>-BES can increase revenue with less transmission capacity and can have value for transmission deferral, especially if revenue is earned for storing CO<sub>2</sub>.

## 3 - Sociotechnical Network Analysis for Power Grid Resilience in South Korea

Daniel Eisenberg, Arizona State University, 1828 Menerini Place, Martinez, CA, 94553, United States, Thomas Seager, Jeryang Park

Critical infrastructure resilience depends on the functionality of technical components and the actions taken by people to adapt to surprise. Here, we study how social and technical networks influence each other by linking a network model of blackout management in South Korea to a corresponding electric power grid network. Results show that Korean power companies receiving equivalent treatment in emergency management protocols are affected by blackouts in markedly different ways. Also, the comparison between static and time-variant analyses indicate that the roles of organizations shift depending on methods used.

## ■ MA44

North Bldg 227C

## Computational Problems Related to Optimal Power Flow

Sponsored: Energy, Natural Res & the Environment/Electricity

Sponsored Session

Chair: Andy Sun, Georgia Institute of Technology, Atlanta, GA, 30312, United States

## 1 - A Stability-constrained Optimization Framework for Nonlinear Systems with Applications in Power Grids

Qifeng (Evan) Li, MIT, Cambridge, MA, United States

This talk will present a steady-state optimization framework for nonlinear control systems with their dynamic stability taken into account. Generally, the dynamics of a control system is captured by a set of differential-algebraic equations (DAEs). Adding the DAEs to the steady-state optimization framework as constraints results in a DAE-constrained problem. An existing mature approach for solving the DAE-constrained optimization problems is the “discretize-then-optimize” method. However, it is not suit for solving the DAE-constrained problems in large-scale systems. Differently, the proposed approach estimates the stability region based on a convex Lyapunov function and projects it onto the steady-state domain as algebraic constraints on the control variables of the steady-state optimization problem. The proposed stability-constrained optimization framework can be applied to many types of nonlinear systems, such as Lur’e, polynomial, and non-polynomial systems. In this talk, I will illustrate the idea of the proposed approach based on an application scenario in power grids, which can be formulated as Lur’e systems. The construction of convex Lyapunov functions for Lur’e, polynomial, and non-polynomial systems will also be discussed respectively.

## 2 - Joint State Estimation and Sparse Topology Error Detection for Nonlinear Power Systems

SangWoo Park, UC Berkeley, Berkeley, CA, United States, Reza Mohammadi-Ghazi, Javad Lavaei

This paper proposes a new technique for robust state estimation (SE) in the presence of a small number of topological errors for power systems modeled by AC power flow equations. The developed method leverages the availability of a large volume of SCADA measurements and minimizes the L1 norm of nonconvex residuals augmented by a nonlinear, but convex, regularizer. We show that under mild conditions, the solution obtained by the designed estimator identifies a small subgraph of the network that can be used to find topological errors in the model. Furthermore, we develop a theoretical upper bound on the SE error. The efficacy of the method is demonstrated through numerical simulations on IEEE test systems.

## 3 - Matrix Completion Embedded PDIP Method for SDP Relaxation of Large-scale OPF Problems

Na Li, Harvard University, 33 Oxford Street, MD 147, Cambridge, MA, 02138, United States, Rui Li, Shengwei Mei

Semidefinite programming (SDP) relaxation has been used to solve nonconvex OPF problems. Bottlenecks in solving large-scale SDP with primal-dual interior-point (PDIP) method primarily exist in matrix multiplication, Cholesky

factorization, and eigenvalue decomposition. We revamp the traditional PDIP method by embedding a sparse clique-factorization MC during each PDIP iteration. The MC method avoids substantial consensus equality constraints associated with the existing approaches and is more flexible to be performed in a parallel fashion. Numerical experiments demonstrate the effectiveness of our approaches.

## 4 - Robust Decentralized Secondary Frequency Control in Power Systems: Merits and Trade-Offs

Changhong Zhao, National Renewable Energy Laboratory, Lakewood, CO, 80401, United States, Erik Weitenberg, Yan Jiang, Enrique Mallada, Claudio De Persis, Florian Dörfler

Frequency restoration in power systems is conventionally performed by broadcasting a centralized signal to local controllers. As a result of the energy transition, technological advances, and the scientific interest in distributed control and optimization methods, a plethora of distributed frequency control strategies have been proposed recently that rely on communication amongst local controllers. In this paper we propose a fully decentralized leaky integral controller for frequency restoration that is derived from a classic lag element. We study steady-state, asymptotic optimality, nominal stability, input-to-state stability, noise rejection, transient performance, and robustness properties of this controller in closed loop with a nonlinear and multivariable power system model. We demonstrate that the leaky integral controller can strike an acceptable trade-off between performance and robustness as well as between asymptotic disturbance rejection and transient convergence rate by tuning its DC gain and time constant. We compare our findings to conventional decentralized integral control and distributed averaging-based integral control in theory and simulations.

## ■ MA45

North Bldg 228A

## Joint Session ENRE/Practice Curated: Power Systems Analytics

Sponsored: Energy, Natural Res & the Environment/Electricity

Sponsored Session

Chair: Shmuel S. Oren, University of California-Berkeley, Berkeley, CA, 94720-1777, United States

Co-Chair: Georgios Patsakis, University of California Berkeley, University of California Berkeley, Berkeley, CA, 94702, United States

## 1 - An Oligopoly Power Market Model in Presence of Strategic Prosumers

Sepehr Ramyar, University of California-Santa Cruz, Santa Cruz, CA, United States, Yihsu Chen

We investigate the formation of wholesale power prices in presence of strategic prosumers and analyze how the unconventional behavior of agents capable of consumption and generation at the same time can impact wholesale power markets. In this study, the price is determined endogenously by strategic prosumers along with other market participants. We study the behavior of prosumers under price-taking assumption and then contrast it with results from Cournot oligopoly with strategic prosumers. We discuss and report the results of price and social surplus implications.

## 2 - Sequential Pricing and Intermittent Supply in Electricity Markets with Heterogeneous Traders

Derck Koolen, Rotterdam School of Management, Chris Bennekerslaan 29Q, Rotterdam, 3061EB, Netherlands, Wolfgang Ketter, Liangfei Qiu, Alok Gupta

Motivated by the ongoing integration of renewable energy sources, we analyze sequential market pricing in short-term electricity markets with producers operating under heterogeneous constraints. We propose a multi-stage competitive equilibrium model to analyze retailers and heterogeneous producers’ optimal sequential trading. The simulated value of flexibility, indicating a first-mover advantage, is validated empirically for different countries.

## 3 - Comparison of Tools to Address Profound Uncertainty in Power Systems

Evangelia Spyrou, Johns Hopkins University, 3400 N. Charles Street, Geography and Environmental Engineer, Baltimore, MD, 21218, United States, Benjamin Field Hobbs

Many tools have been developed to aid decision making under uncertainty. However, most power system analyses tend to use a single particular tool such as stochastic programming or robust optimization. Here, we critically review available tools including Robust Decision Making, which is widely used by the climate change adaptation community, and discuss their strengths and weaknesses. We investigate both theoretical properties of the tools and their practical performance through examples drawn from World Bank studies of climate and conflict risks.

#### 4 - A Bound Strengthening Method for Optimal Transmission Switching in Power Systems

Salar Fattahi, University of California-Berkeley, Berkeley, CA, 94702, United States, Javad Lavaei, Alper Atamturk

This paper studies the optimal transmission switching (OTS) problem for power systems. Most of the existing methods for the problem are based on first converting the OTS into a mixed-integer linear program (MILP) or quadratic program (MIQP), and then iteratively solving a series of its convex relaxations. In this work, it is shown that finding the strongest big-M inequalities to be used in an MILP or MIQP formulation of the OTS is NP-hard. Despite the difficulty of obtaining the strongest bounds in general, a simple bound strengthening method is presented to strengthen the convex relaxation of the problem. Remarkable improvements in the performance of the solvers are achieved compared to other methods.

#### ■ MA46

North Bldg 228B

#### The Water-Energy-Food Nexus

Sponsored: Energy, Natural Res & the Environment/Energy

Sponsored Session

Chair: Alexandra M. Newman, Colorado School of Mines, Golden, CO, 80401, United States

##### 1 - Designing River Basin Storage using Optimization

Andy Burrow, Colorado School of Mines, Golden, CO, 80401, United States, Alexandra M. Newman

The ways in which a growing population increases hydrologic demand are often evaluated using simulation models. This research uses data produced by the State of Colorado's Stream Simulation Model as input to an optimization model to determine the flow of unappropriated water so as to minimize the cost of water shortage mitigation while adhering to constraints that force the physical and topographical structures of the river. Solutions combine upstream pumping and new storage in existing reservoirs, as well as storage in new surface and subsurface reservoirs.

##### 2 - Integrated Modeling of Food-energy-water Nexus in Ethiopia

Siram Sankaranarayanan, Johns Hopkins University, Baltimore, MD, United States, Ying Zhang, Jess Carney, Benjamin Zaitchik, Sauleh Ahmad Siddiqui

We present an integrated partial equilibrium model to understand the effects of interventions to improve food, energy, and water security in Ethiopia. We have a food model, which computes the equilibrium land allocated for various crops, and details of the food supply chain each year. This is coupled with an energy model, which models power generation, transmission and consumption. These models are coupled through prices and quantities along their supply chains. The model can be used to assess shifts in welfare under various policies. We run the model under improved irrigation capabilities, which might reduce power generation from hydel plants and understand the difference in welfare.

##### 3 - Optimizing Water Distribution Operation for Providing Energy Demand Flexibility

Konstantinos Oikonomou, University of Utah, Salt Lake City, UT, United States, Masood Parvania

This talk will present a model to optimize the operation of water distribution systems (WDSs) for providing energy flexibility to power systems operation. The proposed model optimizes the operation of pumps and tanks for minimizing the operation cost of WDS, given the expected water demand and electricity prices of the next day. The proposed model then calculates and offers the feasible flexible energy capacity of WDS to the power system operator. The proposed model takes into account the hydraulic operating constraints of water networks, thus ensuring deliverability of the WDS energy flexibility.

##### 4 - Optimal Control of a Single Wave-energy Converter

Mertcan Yetkin, Lehigh University, Bethlehem, PA, United States, Frank E. Curtis, Lawrence V. Snyder, Sudharsan Kalidoss

This research proposes a generic optimal control formulation for a single wave-energy converter (WEC) from an operations research perspective. Our model adds hard and soft constraints on the motion of the WEC in order to promote safe operation of the device. The hydrodynamic coefficients of the system are estimated using simulation. The resulting problem is formulated as a quadratic program (QP) with a non-convex objective function. We demonstrate the trade-off between the safe operation of the device and the power generated. Finally, the optimal control policy is compared to some classical control strategies to illustrate the improvement in the performance.

#### ■ MA47

North Bldg 229A

#### Joint Session Tutorial/HAS: Optimization of Sequential Decision Making for Chronic Diseases: From Data to Decisions

Emerging Topic Session

Chair: Esma S. Gel, Arizona State University, School of Computing, Informatics and, Decision Systems Engineering, Tempe, AZ, 85287-8809, United States

##### 1 - Optimization of Sequential Decision Making for Chronic Diseases: From Data to Decisions

Brian T. Denton, University of Michigan, University of Michigan, Ann Arbor, MI, 48109-2117, United States

Rapid advances in medical interventions for chronic diseases such as cardiovascular disease, cancer, and diabetes have made it possible to detect diseases at early stages and tailor treatment pathways to individual patients based on their risk factors including gender, race/ethnicity, and disease-specific factors. However, the large number of relevant risk factors to be considered, combined with uncertainty in future health outcomes and treatment side effects, makes optimizing these decisions challenging. Randomized trials are the gold standard for selecting treatment interventions but the large number of possible decisions and their high cost makes these trials infeasible. Data-driven operations research methods are showing great promise in helping patients and medical doctors improve decisions about health interventions. Observational data that is now routinely collected in many health systems is a valuable resource for fitting and validating stochastic models for chronic diseases. Moreover, optimization methods for sequential decision making, including Markov decision processes, partially observable Markov decision processes, and reinforcement learning methods, exploit these models to optimize treatment policies that can balance competing criteria such as the harms and benefits associated with treatment of chronic diseases. This tutorial provides an introduction to some of the most commonly used approaches for using raw data for the purpose of optimizing sequential treatment policies. Special attention is paid to the challenges associated with using observational data and the influence of model parameter uncertainty in this context.

#### ■ MA48

North Bldg 229B

#### Empirical Research in Sustainability

Sponsored: Energy, Natural Res & the Environment Environment & Sustainability

Sponsored Session

Chair: Kejia Hu, Vanderbilt University, Nashville, TN, 37215, United States

##### 1 - An Analysis of Time-based Pricing in Retail Electricity Markets

Asligul Serasu Duran, Haskayne School of Business, University of Calgary, Calgary, AB, Canada, Baris Ata, Ozge Islegen

We empirically evaluate the short-term effects of time-based tariffs on the electricity demand, consumer welfare, retailers and the environment. We find that focusing on the peak-load reduction, one can design a flexible time-of-use (TOU) tariff that is simple and predictable yet performs as well as real-time pricing (RTP) given a fixed time horizon for evaluation. The annual electricity bills of consumers decrease only slightly after switching to time-based tariffs, but there can be significant volatility in month to month bills. In contrast, retailers see less volatility in their profits under more flexible tariffs. The environmental impact depends on the electricity market under study.

##### 2 - Retailer Strategies to Encourage Reduced Packaging Adoption

Olga Pak, 105 Carolina Ridge Drive, Columbia, SC, 29229, United States, Michael Galbreth, Mark Ferguson

For manufacturers, the reduction of product packaging is associated with marketing/product positioning risks, like diminished product visibility and lower perceived value. In this paper, we explore the tools retailers can use to mitigate such concerns, and, thus, convince manufacturers to make packaging more operationally efficient and sustainable.



### 3 - A Free Environmental Lunch? The Impact of Environmental Management Systems on Energy Efficiency

Seongkyoon Jeong, Arizona State University, Tempe, AZ, United States, Lee Jaeseok

This study employs novel panel data on energy efficiency obtained from 2,728 South Korean plants operating between 2001 and 2014. We find that the adoption of ISO 14001, the representative environmental management standard, decreases energy efficiency by approximately 4%. The results suggest two main mechanisms through which EMS adoption reduces energy efficiency: 1) the installation of additional facilities for environmental management and 2) intensified environmental management activities. These findings suggest that EMS adoption inevitably produces additional environmental cost. More importantly, we find that this additional cost can be reduced through organizational learning.

### 4 - Are Hazardous Substance Rankings Effective?

Basak Kalkanci, Georgia Institute of Technology, Atlanta, GA, 30339, United States, Wayne Fu, Ravi Subramanian

We empirically investigate the relationship between changes in the relative assessed hazard levels of chemicals and emissions reductions (including the use of source reduction and end-of-pipe treatment) by facilities that use these chemicals. We also examine the moderating effects of operational leanness - an attribute that prior studies have found to be associated with better environmental performance - in the setting wherein the relative assessed hazard levels of chemicals change over time.

## ■ MA49

North Bldg 230

### Optimization and Systems Engineering Methods in Petrochemicals and Energy II

Sponsored: Energy, Natural Res & the Environment/Natural Resources Petrochemicals

Sponsored Session

Chair: Yifu Chen, University of Wisconsin-Madison, Madison, WI, United States

#### 1 - Infeasibility Resolution for Multi-purpose Batch Process Scheduling

Apurva Samudra, Rockwell Automation, Austin, TX, United States, Yash Puranik, Nikolaos Sahinidis, Alexander B. Smith, Bijan Sayyar-Rodsari

We present a systematic approach for infeasibility diagnosis focusing on scheduling problems. Our approach exploits the known structure of scheduling models to isolate interpretable infeasible sets of constraints. We demonstrate the power of the algorithm on infeasible instances of the Westenberger-Kallrath multipurpose batch process modeled using a state-task network (STN) representation. The methodology presented in the paper is able to successfully analyze the cause of infeasibility and provide recommendations for resolving it. We demonstrate how these insights and recommendations can be presented to scheduling operators in an intuitive manner.

#### 2 - Accounting for the Automation System when Scheduling Chemical Plant Operations

Blake C. Rawlings, The University of Michigan, Ann Arbor, MI, 48109, United States, Venkatachalam Avadiappan, Stéphane Lafortune, Christos T. Maravelias, John M. Wassick

Scheduling of chemical plant operations often involves solving an optimization problem, e.g., to maximize throughput. An approximate plant model is typically used to address industrial-scale problems. This introduces the possibility that the resulting schedule is not actually feasible, i.e., it could not be executed in the plant. We present a method based on analyzing a detailed model of the plant's automation system to detect such infeasible schedules. In this case, the scheduling problem can then be solved again with additional constraints to avoid the infeasible schedule. Symbolic model checking is used to perform the analysis of the detailed model.

#### 3 - Mathematical Optimization Based Approaches for the Design of Materials in Energy Applications

Chrysanthos Gounaris, Carnegie Mellon University, Doherty Hall 3107, Dept of Chemical Engineering, Pittsburgh, PA, 15213, United States, Christopher H. Hanselman, Natalie M. Isenberg

Energy process systems rely on the performance of advanced materials that serve as catalysts of chemical reactions or as separators of chemical species. Many of these materials are crystalline in nature, and derive their functionality from the precise placement of atomic building blocks in well-defined lattice positions. In turn, this gives rise to a discrete design space that can be suitably modeled and explored as a mixed-integer optimization problem to identify materials that are nanostructured to perform optimally in given energy-related contexts. Several case studies towards the design of metallic and metal-oxide surfaces, nanoparticles and bulk materials are discussed.

### 4 - An MIP Model and Rolling Horizon Approach for Strategic Shale Gas Development

Nathan D. Blandino, EQT Corporation, Pittsburgh, PA, United States, Markus Gustav Drouven

In this work we address the long term shale gas development problem which involves determining the optimal development strategy for drilling and fracturing gas wells, and producing through a constrained pipeline system. The problem is formulated as a large-scale MIP with a solution strategy that decomposes the problem temporally through a rolling horizon approach in order to extend the overall planning horizon while yielding near optimal solutions. The model and solution approach were developed by the Optimization Engineering department at EQT Corporation, a shale gas developer and the largest producer of natural gas in the United States.

## ■ MA50

North Bldg 231A

### Joint Session Practice/Analytics/Practice Curated: IAAA Winner Reprise: Northwestern University's Marathon Data Visualization Drives Safety

Sponsored: INFORMS Section on Practice (formerly CPMS)

Sponsored Session

Chair: Carrie Beam, University of Arkansas, Walnut Creek, CA, 94596, United States

#### 1 - SAFE (Situational Awareness for Events): A Data Visualization System

Karen Smilowitz, Northwestern University, Industrial Engineering Management Scienc, 2145 Sheridan Road RM D239, Evanston, IL, 60208, United States

Marathons are growing in popularity, requiring significant resources to ensure safety and success. A team from Northwestern University and the Bank of America Chicago Marathon developed a data visualization system that uses analytics to monitor participants and manage resources. The system has been deployed at marathons in Chicago and Houston.

## ■ MA51

North Bldg 231B

### Contemporary Scheduling

Emerging Topic: Project Management and Scheduling, in Memory of Joe Leung,

Emerging Topic Session

Chair: Emrah Cimren, Starbucks, Seattle, WA, 98029, United States

#### 1 - Efficient Approaches for Data-driven Appointment Scheduling

Tugce Gurek, University of California-Berkeley, Etcheverry Hall, Berkeley, CA, 94702, United States, Philip Kaminsky

We consider a stochastic appointment scheduling problem minimizing the expected deviation from the schedule. We develop a sequencing heuristic that directly uses historical data about task duration rather than making distributional assumptions, and analyze worst-case performance of this heuristic. Given this sequence, we develop an algorithm to set the start time of each task.

#### 2 - Efficient Optimization of Energy Costs

Marc E. Posner, Ohio State University, 296 Baker Systems Engineering, 1971 Neil Avenue, Columbus, OH, 43210-1271, United States, Nicholas G. Hall

While scheduling of computer or manufacturing systems can effectively improve energy efficiency, minimizing total energy cost is more difficult under time-of-use tariffs. We study a production problem with discretely variable speeds, where energy usage increases with speed. We describe a strongly polynomial algorithm when tasks arrive at known times within the planning horizon. We also show that a polynomial time algorithm is unlikely to exist for many generalizations of our problem.

#### 3 - A Framework for Fashion Retail Planning

Emrah Cimren, Starbucks, 2401 Utah Ave South, Seattle, WA, 98134, United States

Fashion retailers offer variety of new products and styles at the start of every season and force to clear out stores for the new merchandise by end of the season. Retail planning is a challenging process since every product comes in different styles, colors, and sizes which increase number of stock keeping units exponentially. This talk presents an optimization framework for fashion retail planning. Main objective is to offer right quantity of the right merchandise in the right place at the right time to meet financial goals.

#### 4 - A Parallel Machine Scheduling Problem with Release Dates, Equal Processing Times, and Eligibility Constraints

Kangbok Lee, Associate Professor, POSTECH, 77 Cheongam-Ro, Nam-Gu., POSTECH, Industrial & Management Engineering, Pohang, 37673, Korea, Republic of, Juntaek Hong

We consider a problem of scheduling independent jobs on parallel machines to minimize the total completion time. Each job has a given release date and a set of eligible machines, and all jobs have equal processing times. For the problem with a fixed number of machines, we show its computational complexity of the problem by providing a polynomial time dynamic programming algorithm. For the problem with an arbitrary number of machines, we propose approximation algorithms and they are evaluated by worst-case analysis and numerical experiments.

## ■ MA52

North Bldg 231C

### Social Media and Online Communities

Emerging Topic: Social Media Analytics

Emerging Topic Session

Chair: Sung Won Kim, University of Illinois at Urbana Champaign, Champaign, IL, 61820, United States

#### 1 - Market Sensing from User Review for Product Management

Ujjal Kumar Mukherjee, Assistant Professor, University of Illinois, Urbana-Champaign, 306 Wohlers Hall, 1206 South Sixth Street, Champaign, IL, 61820, United States

In this paper, we use social media data on customer reviews to understand how firms can use this data to sense market reaction to their products and services. We use sentiment analysis and text analysis on customer feedback to show that customer sentiment significantly predicts future market share of products. We also compare and contrast several methods of customer feedback analysis.

#### 2 - Similarity in the Crowd(funding): How Funder and Backer Affinity Contributes to Crowdfunding Choices

Lauren Rhue, Wake Forest University, 1834 Wake Forest Rd, 212 Farrell Hall, Building 60, Winston-Salem, NC, 27106, United States, Jessica M. Clark, Lauren Dahlin

Using Kickstarter data, we capture funder and backer attributes to examine whether they share similar characteristics and whether those similarities shape the propensity to contribute to particular projects. We also examine project similarity to uncover whether backers give to projects in particular categories or communities.

#### 3 - Unsupervised Dimensionality Reduction vs. Supervised Regularization for Classification from Sparse Data

Jessica Clark, University of Maryland, College Park, MD, United States, Foster Provost

There is consensus among existing guidelines that supervised regularization is superior to unsupervised Dimensionality Reduction (DR) techniques for mitigating overfitting in predictive modeling; however, these guidelines do not take into account that the two types of techniques are often used in conjunction. Many published studies using DR for applied data mining fail to compare performance using the original feature set. We experimentally compare binary classification performance using DR features versus original features under numerous conditions, and find that generally, DR does not add value beyond supervised regularization, and can even diminish performance.

## ■ MA53

North Bldg 232A

### Joint Session AMD/RMP: Algorithms and Market Design

Sponsored: Auction and Marketing Design

Sponsored Session

Chair: Robert Day, University of Connecticut, Storrs, CT, 06269-1041, United States

#### 1 - Learnability and Models of Decision Making under Uncertainty

Pathikrit Basu, California Institute of Technology, 1633, Amberwood Drive, South Pasadena, CA, United States, Federico Echenique

We study whether some of the most important models of decision-making under uncertainty are uniformly learnable, in the sense of PAC (probably approximately correct) learnability. Many studies in economics rely on Savage's model of (subjective) expected utility. The expected utility model is known to predict behavior that runs counter to how many agents actually make decisions (the contradiction usually takes the form of agents' choices in the Ellsberg paradox).

#### 2 - Learning and Efficiency in Games with Dynamic Population

Thodoris Lykouris, PhD Candidate, Cornell University, 107 Hoy Road, Gates 336, Ithaca, NY, 14853, United States, Vasilis Syrgkanis, Eva Tardos

We study multi-player game settings (such as online advertising, internet routing, and bandwidth allocation) where the player set is dynamically evolving over time and participants use some learning algorithms to adapt to the changing environment. Traditional equilibrium notions require too much information for the players since they need to form perfect beliefs about the behaviors of others and do not extend to dynamic settings. In contrast, we show that, under the learning behavioral assumption, players reach outcomes of high quality (measured by the social welfare) even when there is a high churn in the population.

#### 3 - Selling to a No-regret Buyer

Jieming Mao, Princeton University, Princeton, NJ, United States, Mark Braverman, Jon Schneider, Matt Weinberg

We consider the problem of a single seller repeatedly selling a single item to a single buyer (specifically, the buyer has a value drawn fresh from known distribution  $D$  in every round). Prior work assumes that the buyer is fully rational and will perfectly reason about how their bids today affect the seller's decisions tomorrow. In this work we initiate a different direction: the buyer simply runs a no-regret learning algorithm over possible bids. We provide a fairly complete characterization of optimal auctions for the seller in this domain.

#### 4 - Optimal Data Acquisition for Statistical Estimation

Juba Ziani, California Institute of Technology, Pasadena, CA, United States, Yiling Chen, Nicole Immorlica, Brendan Lucier, Vasilis Syrgkanis

We consider a data analyst's problem of purchasing data from strategic agents to compute an unbiased estimate of a statistic of interest. Agents incur private costs to reveal their data and the costs can be arbitrarily correlated with their data. We design an individually rational and incentive compatible mechanism that optimizes the worst-case (over the unknown correlation between costs and data) mean-squared error of the estimation, subject to a budget constraint. We give the optimal mechanism in closed-form. We extend our results to acquiring data for estimating a parameter in regression analysis, where private costs can only correlate with the values of the dependent variable.

## ■ MA54

North Bldg 232B

### Leveraging Human Intelligence Alongside Analytical Models

Sponsored: Behavioral Operations Management

Sponsored Session

Chair: Blair Flicker, University of Texas-Dallas, Richardson, TX

#### 1 - Managerial Insight and "Optimal" Algorithms

Blair Flicker, University of Texas-Dallas, Richardson, TX, 75208, United States

Stylized models omit many real-world phenomena, and such model misspecification degrades the performance of "optimal" policies in practice. By accounting for unmodeled dynamics, human managers can improve decision making. I formalize "managerial insight" (noisy signal of demand observable only by humans) and apply it to the newsvendor setting. With superior demand information, human newsvendors should improve profits, but experiments reveal costly suboptimal ordering. I recast the newsvendor task as a forecasting task and develop an algorithm to convert forecasts to orders. In the lab, this human-machine hybrid approach consistently outperforms either humans or machines operating alone.

#### 2 - Can We Improve Analytical Models through Judgement and Local Information

Han Oh, Texas A&M University, College Station, TX, 77843, United States, Rogelio Oliva

Using data from a large retailer, we identify the triggers for managers modifying re-stocking order recommendations from a centralized information system and evaluate the performance of such modifications. Our analysis shows that local managers do have local information that adds value to the overall decision making - thereby improving the performance of a centralized information system.

#### 3 - When Models Meet Managers: Integrating Judgmental and Statistical Model-Based Forecasting

John Aloysius, University of Arkansas, Supply Chain Management Department, Wcob 204, Fayetteville, AR, 72701, United States, Enno Siemsen, Rebekah Brau

Technology-enabled big data analytics and machine learning is increasingly a feature of forecasting in practice. However, practitioners continue to use judgment to incorporate private information to improve the accuracy of forecasts generated by statistical models. Our research examines how statistical models and human judgment may be integrated to improve forecast accuracy in different forecasting environments.

#### 4 - A Structured Solution of Prescriptive Analytics: Theory and Experiment

Justin Jia, Purdue University, West Lafayette, IN, United States,  
Elena Katok

Prescriptive analytics problem is when a decision maker solves an optimization problem with uncertainty without knowing the distribution of the random variables, but has a sample. Our insight is that we show that the decision, which is a high-dimensional function of the sample, can be reduced to a simple single-dimensional function of a sufficient analytic statistic. We report on a controlled laboratory experiment with human subjects, and show that behavior qualitatively matches theoretical predictions.

### ■ MA55

North Bldg 232C

#### He for She: What Does it Mean for Us at INFORMS

Sponsored: Women in OR/MS (WORMS)

Sponsored Session

Chair: Dorothee Honhon, University of Texas at Dallas, Richardson, TX, 75080, United States

Co-Chair: Margarit Khachatryan, MagAnalytics, Bridgeton, MO, 63044, United States

##### 1 - Moderator

Margarit Khachatryan, Founder, MagAnalytics, St. Louis, MO, 63044, United States

In this panel session, a group of influential male speakers will discuss how we can best support women in OR/MS. They will share their experiences working with/for female colleagues, and supervising/mentoring them. They will discuss family-focused, anti-discrimination and sexual harassment institutional policies and share tips on how to make our work places a friendly and safe environment for women and other minorities.

##### Panelists

Rohit Verma, NY, United States

Anton Ovchinnikov, Queen's School of Business, 143 Union Street, Kingston, ON, K7L 3N6, Canada

Richard G. McGrath, United States Naval Academy, Annapolis, MD, United States

Rishabh Bhandawat, University at Buffalo, 25HA Creekside Village, Buffalo, NY, 14261, United States

Leon McGinnis, Georgia Institute of Technology, Isye Dept, 755 Ferst Drive, Atlanta, GA, 30332-0205, United States

Gregory James King, GAP, San Francisco, CA, United States

### ■ MA56

West Bldg 101A

#### Joint Session DM/HAS: Patient-Centered Health Care

Sponsored: Health Applications

Sponsored Session

Chair: Guihua Wang, Ann Arbor, MI, 48105, United States

##### 1 - Driving Personalized Health Care through Heterogeneous Data Analysis

Guihua Wang, Ross School of Business, University of Michigan, 701 Tappan Street, Ann Arbor, MI, 48105, United States, Jun Li, Wallace J. Hopp

This study addresses the challenges of generating patient-centric outcome information. Using patient-level data from thirty-five hospitals for six cardiovascular surgeries in New York State, we identify patient groups that exhibit significant differences in outcomes with a new instrumental variable tree approach. We find that outcome differences between hospitals are heterogeneous not only across procedure types, but also along other dimensions such as patient age and comorbidities. We illustrate how patient-centric information can help patients make more informed decisions, payers enhance pay-for-performance programs, and providers target quality improvement efforts.

##### 2 - An Analytics Approach to Predicting Treatment Effectiveness: Inter-hospital Transfer of Heart Attack Patients

Susan F. Lu, Purdue University, Krannert 441, West Lafayette, IN, 47907, United States, Qi Feng, George Shanthikumar

Healthcare regionalization is an important topic for the on-going healthcare reform. In this study, we integrate healthcare domain knowledge based structural model into data analytics and apply the method to study the inter-hospital

transfer of heart attack patients. We developed a two-stage support vector machine model to identify heart attack patients who need to be transferred immediately given the limited revascularization resources. Our recommendation performed far better than physicians' decisions in terms of expected lives saved.

##### 3 - Managing the Portfolio of Elective Surgical Procedures

Hessam Bavafa, Wisconsin School of Business, 4284C Grainger Hall, 975 University Avenue, Madison, WI, 53706, United States, Sergei Savin, Lerzan E. Ormeci

We consider the problem of allocating daily hospital service capacity among several types of elective surgical procedures. Our focus is on the interaction between two major, constraining hospital resources: operating room and recovery bed capacity. In our model, each type of surgical procedure has an associated revenue, stochastic procedure duration, and stochastic length-of-stay (LOS). We consider arbitrary distributions of procedure and LOS durations and derive a two-moment approximation for the total procedure duration and the daily number of occupied beds for a given portfolio of procedures.

##### 4 - Using Episodes of Care to Examine Mental Healthcare Quality

Jayakanth Srinivasan, Questrom School of Business, Boston, MA, United States

Episodes of care are useful for integrating the discrete, itemized world view obtained from traditional healthcare utilization data. In this paper, we show how care trajectories can be constructed for Soldiers using de-identified data, and calculate gross measures of resource utilization in the outpatient and inpatient settings at two Army hospitals. I compare two approaches for constructing episodes of mental healthcare within these care trajectories, the first using only administrative data, and the second incorporating heuristics obtained from field research on health systems operations. The approaches developed in this paper provide a new lens for examining quality and patient safety.

### ■ MA57

West Bldg 101B

#### Emergency Management

Sponsored: Health Applications

Sponsored Session

Chair: Douglas R. Bish, Virginia Tech, Blacksburg, VA, 24061, United States

Co-Chair: Paul Bartholomew, VA, United States

##### 1 - Multi-class Casualties Distribution in Mass Casualty Incidents

Zheqi Zhang, University of North Carolina, Chapel Hill, NC, United States

We study the patient distribution problem in the mass casualty incidents aims to maximize the expected number of survivors. Our Markov decision process(MDP) model assumes patients triaged into two classes distinguished by survival probabilities and medical needs. The decision is to prioritize and distribute patients by limited ambulances to hospitals with different capabilities and capacities. We explicitly modeled the ED and operating room capacities to capture the possible congestion. Base on this MDP formulation, we propose heuristic policies and employ discrete-event simulations to demonstrate the benefits of using the proposed heuristics against benchmark policies from practice.

##### 2 - Coordinating Regional Response to a Mass-casualty Incident

Paul Bartholomew, Virginia Tech, Blacksburg, VA, 24060, United States, Douglas R. Bish, Behrooz Kamali

We study optimally coordinating the response to a mass-casualty incident. An effective response requires coordination of several entities including first responders and hospitals in the region. We develop a model that determines the service order for the casualties and hospital assignment, given hospital and transportation resources. The objective of the model is to maximize the total survival probability using a novel function that accounts for type of the casualty, travel distance, and receiving hospital's quality of care. We compare the results from our model to common real-world policies and relevant studies in the literature and analyze the performance under various resource settings.

##### 3 - Emergency Preparedness and Response for Mass Gatherings

Mohammadreza Torkjazi, Graduate Research Assistant, West Virginia University, Morgantown, WV, United States, Behrooz Kamali

A mass gathering (MG) is an event where a large crowd gathers. This creates a risk of delayed and/or limited response to emergencies. In this research, we propose a framework to quantify and measure this risk by identifying factors affecting the risk and classify them into multiple categories. Then, using "controllable" factors in each category, we develop a mathematical model to minimize the risk exposure to casualties by improving the flow of response. We present several case studies to demonstrate the effectiveness of our approach and analyze its sensitivity to various factors.



#### 4 - Patient Admission Decision at Emergency Department under Mass Casualty Incident

Taesik Lee, KAIST, 291 Daehak-ro, Yuseong-gu, Daejeon, Korea,  
Republic of, Hyun-Rok Lee

In the aftermath of a mass casualty incident, an emergency department (ED) may divert less critical patients to preserve its resources for possible future arrivals of more critical ones. Justification for the diversion is to increase the overall expected survival of the entire casualties. When this decision making is a challenge for a single ED case, multiple ED environment makes it even more difficult. We formulate the problem as a decentralized partially observable MDP model, where individual EDs make a diversion decision with only partial information on other EDs' state. Heuristic solution techniques to approximately solve the model are presented and compared for their performance.

#### ■ MA58

West Bldg 101C

#### Operations Research for Medical Decision Making

Sponsored: Health Applications

Sponsored Session

Chair: Brian T. Denton, University of Michigan, Ann Arbor, MI, 48109-2117, United States

Co-Chair: Lauren N. Steimle, University of Michigan, Ann Arbor, MI, 48105, United States

#### 1 - Robust Personalized Treatment Selection for Partially Observable Chronic Conditions

Jue Gong, University of Washington, Seattle, WA, 98115,  
United States, Shan Liu

For many chronic diseases, an individual patient may experience many progression pathways. Developing a personalized treatment plan is a difficult sequential decision-making problem. The natural stochasticity of the disease progression makes the estimation of the disease model difficult, and inaccurate model reduces the performance of the treatment selection strategy. We will develop novel approaches for modeling the uncertainties in individual disease progression and finding the robust POMDP policy optimal for individual patients. A data-driven method to construct or calibrate the uncertainty set is required to guarantee the effectiveness of the individualized robust policy.

#### 2 - Ovarian Cancer Prevention and Risk Reduction:

##### A Model-based Analysis

Julia L. Hagle, University of Southern California, University Park  
Campus, GER 240B, Los Angeles, CA, 90089-0193, United States,  
Jing Voon Chen

Recent studies indicate the existence of fallopian tube lesions as a precursor to serous ovarian cancer, the most aggressive form of ovarian cancer. This suggests an opportunity for prevention of serous ovarian cancer through surgical removal of the fallopian tubes (salpingectomy). Using a model of ovarian cancer that is differentiated by patient risk (i.e., genetic mutation status) and ovarian cancer sub-type, we examine the potential impact of prophylactic salpingectomy.

#### 3 - Behavioral Intervention Design using Precision Analytics

Yonatan Mintz, UC Berkeley, Berkeley, CA, United States,  
Anil Aswani, Philip Kaminsky, Elena Flowers, Yoshimi Fukuoka

In this talk, we describe a precision analytics framework that uses patient data to effectively design personalized weight loss interventions. Our framework utilizes a utility maximization model for patient behavior which combined with integer programming and Bayesian prediction allows us to create several personalized interventions, as well as aggregate these interventions into a cohort weight loss program. We then present clinical trial and simulation results which show that our method maintains efficacy while potentially reducing the associated person hours and cost of the intervention.

#### 4 - Two-step Markov Process Methodology for Parameterizing Cancer State Transitions in Limited-data Settings

Chaitra Gopalappa, University of Massachusetts Amherst, 160  
Governors Dr, Amherst, MA, 01003, United States, Guo Jiachen,  
Prashant Meckoni, Buyannemekh Munkhbat, Carel Pretorius,  
Jeremy Lauer, Andre Ilbawi, Melanie Bertram

Among all premature deaths from non-communicable diseases (NCDs) reported globally, 90% occurred in low and middle income countries. To address this burden, the WHO-CHOICE analyses developed a map of the 'Best Buy' interventions to update the Global NCD Action Plan for 2013-2020. The evidence for 'Best Buys' were based on model predictions of cost-effectiveness of alternative intervention scenarios. Our team developed models and predictions for 3 types of cancers, breast cancer, colorectal cancer, and cervical cancer, including a new methodology for parameterizing a natural history model for countries where longitudinal cancer registry databases are not available. We will present this work.

#### ■ MA59

West Bldg 102A

#### Teams in Healthcare Delivery

Sponsored: Health Applications

Sponsored Session

Chair: Song-Hee Kim, CA, United States

#### 1 - Collaboration, Interruptions and Changeover Times: Model and Empirical Study of Hospitalist Processing Times

Itai Gurvich, Cornell University, 2 W. Loop Rd, New York, NY,  
10044, United States, Jan A. Van Mieghem, Kevin O'Leary,  
Lu Wang

Collaboration may lead to interruptions. Task switching can introduce changeover times when resuming the preempted task and thus can increase total processing time. We analyze and quantify how collaboration, through interruptions and discretionary changeovers, affects total processing time. We introduce an episodic workflow model that captures the interruption and discretionary changeovers dynamics—each switch and the episode of work it preempts—present in settings where collaboration and multitasking is paramount. We then deploy the model in a field study of hospital medicine physicians—"hospitalists" to estimate the total changeover time they incur.

#### 2 - Learning from Many: Partner Exposure and Team Familiarity in Fluid Teams

Jonas Oddur Jonasson, MIT Sloan School of Management, 30  
Memorial Drive, E62-588, Cambridge, MA, 02142, United States,  
Zeynep O. Aksin Karaesmen, Sarang Deo, Kamalini Ramdas

We use data from London Ambulance Service to study the impact of partner exposure of new paramedics on their operational performance. We find that greater prior partner exposure directly improves performance for an unstandardized process. For a more standardized process, this effect is moderated by a new recruit's total experience. For both processes the effect is more pronounced at times of high workload. We explore the implications of our results for team formation strategies by balancing the benefits of partner diversity with those of team familiarity.

#### 3 - Cross-disciplinary Temporary Teams in Health Care

##### Organizations: The Role of Partner Variety and Shared Experience

Hummy Song, The Wharton School, University of Pennsylvania,  
3730 Walnut Street, 560 Jon M. Huntsman Hall, Philadelphia, PA,  
19104, United States, Song-Hee Kim, Melissa Valentine

We examine how managers can compose temporary teams of cross-disciplinary health care professionals to facilitate team performance. We leverage random team and task assignment in an emergency department to identify the performance effects of shared experience and partner variety as they are accumulated within a shift versus over the longer term among physicians and nurses. We propose easily implementable managerial recommendations. Using simulation, we illustrate that the gains in patient throughput would be substantial, even without increasing staffing levels.

#### 4 - Toward an Effective Design of Preventive Health Care Delivery: Collaboration with Primary Care Providers

Yingchao Lan, Ohio State University, 2100 Neil Avenue,  
Fisher Hall 252C, Columbus, OH, 43210, United States,  
Aravind Chandrasekaran

Chronic diseases are responsible for 70% deaths among Americans each year and around 75% of the nation's health spending. While both practitioners and researchers have recognized the importance to design an effective preventive care delivery system to improve population health and health delivery efficiency, it's still unclear how. This paper addresses this gap by studying how collaboration with primary care providers can improve population health and healthcare delivery efficiency.

## ■ MA60

West Bldg 102B

### HAS Session

Sponsored: Health Applications

Sponsored Session

Chair: Van-Anh Truong, Columbia University, New York, NY, 10027, United States

#### 1 - Continuum of Care for Reducing Readmissions: Balancing Pre- and Post-discharge Efforts

Xiang Liu, University of Michigan, 1205 Beal Ave, Ann Arbor, MI, 48109, United States, Mariel Sofia Lavieri, Jonathan Helm, Ted Skolarus

Hospital readmissions are burdensome and costly. We analytically study, under a Bundled Payment (BP) policy 1) how hospitals balance effort between the inpatient stay stage and the post-discharge stage; and 2) how a public healthcare funder designs a BP policy and readmission penalty program to incentivize hospitals to balance its efforts for readmissions reduction. We develop a novel Strengthen Then Maintain (STM) framework that is generalizable to a set of machine maintenance problems. We uncover novel managerial insights for the design of BP policies and readmission penalty programs.

#### 2 - Optimizing Discharge Decisions in a Hematology Ward

Mor Armony, New York University, 44 West 4th Street #8-62, New York, NY, 10012, United States, Galit Bracha Yom-Tov

Following treatment hematology patients face an increased risk of developing an infection. If a patient remains at the hospital his risk of catching an infection is higher than at home, but once an infection develops the mortality risk at the hospital is lower than at home due to quick access to appropriate treatment. We study the problem of dynamically determining discharge times for hematology patients subject to capacity constraints. We show that in an overloaded operating regime this dynamic problem reduces to a static problem with a simple solution of two-class two-discharge thresholds. We characterize the specific optimal solutions under empirically driven time-to-infection distributions.

#### 3 - Online Resources Allocation with Learning and Reoptimization

Zhen Xu, Columbia University, New York City, NY, 10027, United States, Van Anh Truong

We study a multi-period revenue management problem where a decision maker assigns each arriving customer to one of multiple products made from multiple resources with finite capacity. Every assignment of a customer to a product will generate a random reward. The objective is to jointly learn the mean reward function and maximize the expected revenue. We formulate the problem as a multi-armed bandit problem. We propose a natural and simple extension of the UCB family of algorithms. We show that by taking advantage of re-optimization techniques, our proposed algorithm achieves a regret of  $O(\log^3 T)$ , which significantly reduces the  $O(\sqrt{T})$  bound.

#### 4 - Toward a Genomic Liquid Biopsy

Andrew A. Li, MIT, Cambridge, MA, United States, Jackie W. Baek, Vivek Farias, Chinmay Jha, Deeksha Sinha

The cost of DNA sequencing has fallen 10,000x in the last ten years, and we are finally in sight of the silver bullet for cancer screening: an early-stage blood test. As sequencing can now be performed affordably on a tiny fraction of a genome, what remains is a massive variable selection problem. We provide an efficient algorithm, based on a decomposition at the gene level, that scales to full genomic sequences across thousands of patients. We contrast our selected variables against DNA panels from two recent, high-profile studies and demonstrate that our own panels achieve significantly higher sensitivities at the same cost, along with accurate discrimination between cancer types for the first time.

## ■ MA61

West Bldg 102C

### Advocacy and Elections: A Discussion about the INFORMS Advocacy Initiative and the 2018 Midterm Elections

Emerging Topic: INFORMS Special Sessions

Emerging Topic Session

Chair: Jeff Cohen, INFORMS, 5521 Research Park Drive, Suite 200, Catonsville, MD, 21228, United States

#### 1 - Advocacy and Elections: a Discussion about the INFORMS Advocacy Initiative and the 2018 Midterm Elections

Jeff Cohen, INFORMS, 5521 Research Park Drive, Suite 200, Catonsville, MD, 21228, United States

In 2018 INFORMS launched a new advocacy initiative to raise policymakers' awareness and interest in the O.R. and Analytics fields, build strategic relationships between INFORMS and the policy community, and enable

INFORMS to become a trusted source of expertise. Led by INFORMS Director of Public Affairs & Marketing Jeff Cohen and Signal Group Executive Vice President Charles Cooper, this session will provide an update about INFORMS' advocacy activities, including the INFORMS Government & Analytics Summit. The session will also include a discussion about the overall current state of Washington, an analysis of the 2018 mid-term election polls and predictions, and the practical impacts and implications of different election day outcomes.

#### Panelist

Charles Cooper, SIGNAL, Washington, DC, United States

## ■ MA62

West Bldg 103A

### Data-Driven Decision Making

Sponsored: Data Mining

Sponsored Session

Chair: Milton Soto-Ferrari, Indiana State University, Scott College of Business, Terre Haute, IN

#### 1 - Integrating CAP Domains into Analytics Courses: Methods & Examples

Concetta A. DePaolo, Indiana State University, Scott College of Business, Terre Haute, IN, 47809, United States

The Certified Analytics Professional (CAP®) designates competencies or domains for analytics professionals. This presentation will describe how these domains have been integrated into an undergraduate business analytics course. In addition, examples of case studies involving real-world data used to teach analytics process and methods will be shared.

#### 2 - Frontier Estimation for Automated Machine Levels Outputs

Sandeep Bhowmick, Indiana State University, Terre Haute, IN, United States

As an alternative to data envelopment analysis, Frontier estimation methods have been found to be more efficient in estimating efficiency measures. Separating random noise component into stochastic and non-stochastic components is found useful in capturing efficiency components of production methods. This presentation shows an application of stochastic frontier estimation method to analyze efficiency values on an industry supplied data at automated machine level outputs.

#### 3 - A Method for Systematic Monitoring of Treatment Receipt in Breast Cancer Patients

Milton Soto-Ferrari, Indiana State University, 30 N. 7th St, Room F-211, Terre Haute, IN, 47807, United States

This research aims to propose a method to monitor the clinical and non-clinical variables that influence the receipt and adherence to treatment in breast cancer patients. Building upon a Bayesian Network model for mining cancer registry data. The method presents a framework for the automatic monitoring of patients to predict radiation treatment receipt. This framework uses information from a regional cancer institution with a sample of 1922 patients from years 2009-2014.

## ■ MA63

West Bldg 103B

### Joint Session DM/AI: Deep Learning in Text Mining and Analytics

Sponsored: Data Mining

Sponsored Session

Chair: Onur Seref, Virginia Tech, Blacksburg, VA

#### 1 - Adverse Drug Events Detection and Recognition: A Deep Learning Based Approach

Long Xia, Virginia Polytechnic Institute and State University, 880 W. Campus Drive, 2069 Pamplin Hall, Blacksburg, VA, 24061, United States,

Drug safety profiling plays a significant role in medications decision-making. Analyzing the adverse drug events from patients' generated data is an integral part of drug safety profiling. With the practical need for advanced text mining techniques for adverse drug events identification and extraction, we proposed a research framework which utilizes deep learning network as the platform, incorporates both word embeddings features and features obtained from existing models to complement feature coverage and comprehensiveness. By further incorporating human designed features, our approach achieved a significantly improved performance.

## 2 - Effects of User-provided Photos on Hotel Review Helpfulness: An Analytical Approach with Deep Learning

Qianzhou Du, Virginia Tech, Blacksburg, VA, United States,  
Weiguo Fan, Zheng Xiang

Online reviews have been studied in the hospitality and tourism literature. However, while user provided photos embedded in online reviews accumulate in large quantities, their informational value has not been well understood likely due to technical challenges. The goal of this study is to introduce deep learning for computer vision to understand information value of online hotel reviews. Using a dataset collected from two social media sites, we compared deep learning models with other machine learning techniques to examine the effect of user-provided photos on review helpfulness. Findings show that deep learning models are more useful in predicting review helpfulness than other models.

## 3 - Deep Learning-based Sentence-level User Feedback Classification in Mobile App Reviews

Zhilei Qiao, Virginia Institute of Technology, 880 West Campus Drive, Blacksburg, VA, 24061, United States, Alan Gang Wang, Alan Abrahams, Weiguo Fan

It is important for app developers to efficiently extract and understand user needs from online reviews. However, discovering and quantifying potential user needs from massive online reviews is a nontrivial task. In this paper, I propose a domain-oriented deep learning framework that can discover the most critical user needs such as new product features and bug reports from online reviews. I conduct a systematic evaluation to ensure the quality of discovered information. Experimental results demonstrate that the proposed framework outperforms the baseline models. This research has significant managerial implications for app developers.

## 4 - Understanding Meaning of Text in its Context – A Network-based Text Mining Model for Discovering Context Clues

Sukhwa Hong, Virginia Institute of Technology, Pamplin College of Business, 880 West Campus Drive, Blacksburg, VA, 24061, United States, Onur Seref, Michelle MH Seref

We present a network-based framework to identify and cluster phrases or phrases with context clues in classes of text data using prevalence scores of n-gram structures and their connections. Our framework extends the bag-of-words models by network-based clustering methods to create sub-graphs of connected n-grams for finding context clues. The paths in these sub-graphs represent sequences of words, which form connected phrases with richer contextual meaning. We use our method to identify variations of these phrases and apply the proposed framework to study a collection of customer reviews from TripAdvisor and Yelp.

## MA64

West Bldg 104A

## Joint Session DM/Practice Curated: Data Science and Analytics in Healthcare II

Sponsored: Data Mining

Sponsored Session

Chair: Durai Sundaramoorthi, Washington University in Saint Louis, 10352 Conway Road, Saint Louis, MO, 63131, United States

## 1 - Machine Learning Based Hypoglycemia Recognition from Driving Patterns in Individuals with Diabetes Mellitus

Mathias Kraus, ETH Zuerich, Zuerich, Switzerland, Stefan Feuerriegel, Elgar Fleisch, Tobias Kowatsch, Markus Laimer, Christoph Stettler, Felix Wortmann, Thomas Z ger

Hypoglycemia has consistently been shown to be associated with an increased risk of driving mishaps. As a prevention, we propose to utilize machine learning models to detect and predict hypoglycemia based on driving behavior. We compare data about the driving behavior by tracking individuals with/without hypoglycemic condition. Our preliminary evaluation using a driving simulator confirm the effectiveness of our approach.

## 2 - Using Machine Learning Techniques to Determine Preterm Birth Risk Factors

Alireza Ebrahimvandi, Virginia Tech, Blacksburg, VA, 24060, United States

Preterm birth (before 37 weeks) is a major health issue in the US and its predictors are poorly known. Prior studies applied machine learning techniques to identify variables that can predict preterm. We will use two machine learning techniques: lasso regression and support vector machines on a much larger dataset obtained from Center for Disease Control to identify key predictors of preterm. We expect to improve sensitivity of prediction by using a larger dataset. Improving one percent sensitivity of prediction tests is valuable because every preterm birth costs about \$10,000, and 1% decrease in preterm births translates to half a billion dollars saving plus preventing long life deficiencies.

## 3 - Combining Observational Data and Meta-analysis Results for Evaluating Impact of Behavior Changes on Disability Adjusted Life Years

Ozden F. Gur Ali, Koc University, College of Administrative Sciences, Rumeli Feneri Yolu Sariyer, Istanbul, 34450, Turkey, Angi Ghanem

We introduce a method to combine individual level observational data with meta-analysis results of extant research to evaluate the potential impact of a public health intervention. We show that both pieces of information are needed to get causally defensible models that reflect the local effects, adjust for important individual level covariates, and guard against confounding. We apply the method to provide point and interval estimates of the impact of changes in behaviors like physical exercise, smoking, and diet on disability adjusted life years (DALY) due to prevalence of heart disease and diabetes.

## MA65

West Bldg 104B

## Joint Session APS/Opt-Uncert/Practice Curated: APS Session Uday

Sponsored: Applied Probability

Sponsored Session

Chair: Uday Shanbhag, Pennsylvania State University, University Park, PA, 16803, United States

## 1 - Randomized Push-pull Method for Optimization on Graphs

Angelia Nedich, ASU, 650 E. Tayler Mall, Goldwater Center, Rm 311, Tempe, AZ, 85281, United States

We consider a randomized push-pull algorithm for distributed optimization on graphs. The method is based on a random asynchronous implementation of push-pull method recently proposed for minimizing the sum of the agents' cost functions in a network that obeys the network connectivity structure. In order to minimize the sum of the cost functions, a new distributed gradient-based method where each node maintains two estimates, namely, an estimate of the optimal decision variable and an estimate of the gradient for the average of the agents' objective functions. We show convergence results for the method over a directed static network.

## 2 - Estimating Optimality Gaps for Stochastic Optimization via Bootstrap Aggregating

Henry Lam, Columbia University, 500 W. 120th St., New York, NY, 10027, United States, Huajie Qian

We present approaches to estimate the optimality gaps of solutions in stochastic optimization using limited data. Our approaches are based on bootstrap aggregating that can demonstrably improve the tightness-variance tradeoff incurred in existing methods. We present our theories and show numerical effectiveness through some examples.

## 3 - Asymptotic Results on Two-stage Stochastic Quadratic Programming

Junyi Liu, University of Southern California, 30 Virginia Avenue, Los Angeles, CA, 91107, United States, Suvrajeet Sen

In this talk, we will present stochastic decomposition (SD) algorithms for two-stage stochastic quadratic programming (STQP) problem. Based on their stochastic linear programming (SLP) predecessor, these iterative schemes in SD algorithm approximate the objective function using affine/quadratic minorants and then apply a stochastic proximal mapping to obtain the next iterate. We show that under certain assumptions the proximal mapping applied in SD obey a non-expansive mapping property and study the convergence rate of SD to the optimal solutions.

## 4 - Smoothing and Acceleration for Stochastic Convex Optimization

Afrooz Jalilzadeh, Pennsylvania State University, 310 Leonhard Building, University Park, PA, 16803, United States, Uday Shanbhag

We consider a class of structured nonsmooth stochastic convex problems. By integrating smoothing, Nesterov acceleration, and increasing batch-sizes, we show that Nesterov's rate of  $O(1/k)$  may be recovered while under strong convexity, a linear rate of convergence is attained. We comment on special cases in the convex regime when the problem is either smooth or merely deterministic.



## ■ MA66

West Bldg 105A

### ROI of AI: Value and Operational Implications of Artificial Intelligence

Sponsored: Artificial Intelligence

Sponsored Session

Chair: Nigel P. Melville, University of Michigan, Ann Arbor, MI, 48109-1234, United States

#### 1 - Scientometric Review of Business and Operations AI Literature

Nigel P. Melville, University of Michigan, Stephen M. Ross School of Business, 701 Tappan Street, Ann Arbor, MI, 48109-1234, United States

Artificial intelligence is rapidly diffusing across industries. Though firms are employing AI in a variety of contexts for a variety of benefits, research examining the business impacts and implications of AI is not abundant. This paper employs scientometrics to identify and synthesize such research and pose a set of research questions to lay the groundwork for future studies of the impacts and implications of AI in business contexts.

#### 2 - Artificial Intelligence: How Customer Reactions Impact Innovation

Lisa Yeo, University of California, Merced, Merced, CA, United States, Erik Rolland, Jacquelyn Rees Ulmer, Raymond Patterson

Artificial Intelligence (AI) technologies are often included as product features (e.g. facial or voice recognition, autonomous driving systems) that drive product and service innovation. However, such innovations increase software complexity, leading to security and privacy issues. Customer reactions to security or privacy failures may affect product demand; customer demand reaction to the security or privacy implications of new features, such as AI-driven technology, plays a role in regulating the rate of innovation. This work examines the trade-off between product innovation and the increased risk of security breaches in AI-enabled products and services.

#### 3 - Who's Watching TV

Jessica Clark, University of Maryland, Jean-Francois Paiement, Foster Provost

This work introduces the novel problem of “user disambiguation”: estimating the likelihood of each member of a small group using a shared account or device. Specifically, we focus on television Set-Top Box viewership data in multi-person households. Our contributions include formulating a predictive problem; developing a method for estimating individuals' viewership which learns priors for viewership in single-person households then adapts them to the specifics of each multi-person household's viewership history; and evaluating our new method via a comparison to two ad-hoc heuristics currently used for estimating TV audience composition.

#### 4 - To Predict or Not to Predict: The Case of Inpatient Admissions from the Emergency Department

Sriram Somanchi, University of Notre Dame, 344 Mendoza College of Business, University of Notre Dame, Notre Dame, IN, 46556, United States, Idris Adjerid

Novel statistical methods have the potential to dramatically improve the efficiency and quality of healthcare. However, dynamic processes and complex infrastructures result in the data with highly variable acquisition costs. We offer a novel and generalizable method that helps reduce the cost while maintaining high accuracy. We utilize this approach in the Emergency Department (ED) context. Specifically, we focus on accurately predicting whether an ED patient will be admitted to an interior hospital unit or discharged from the ED, while minimizing the time-cost of prediction. We show this reduction in time-cost of prediction could translate into a 20% reduction in total time in the ED per patient.

## ■ MA67

West Bldg 105B

### Field Experiment in Online Marketplace and Social Network

Sponsored: Information Systems

Sponsored Session

Chair: Tianshu Sun, University of Southern California

#### 1 - Word-of-mouth System Implementation and Customer Conversion: A Randomized Field Experiment

Ni Huang, Arizona State University, 832 W. Wagner Dr, Arizona, Gilbert, AZ, 85233, United States, Tianshu Sun, Pei-yu Chen, Joseph Golden

E-commerce firms often face the decision on whether they should implement a word-of-mouth (WOM) system on their websites. An in-site WOM system can potentially boost customer conversion by conveying signals and information

about product popularity and quality. However, implementing such a system might also have unintended consequences, hindering product sales due to the lack of control over WOM volume and content. This study examines how implementing a WOM system (through social media integration) on an e-commerce website affects customer conversion in the two stages of consumer purchase funnel, namely, adding a product to cart and placing an order.

#### 2 - Be Gentle to the Newbies: A Randomized Field Experiment on Negative Feedback in Online Communities

Wei Chen, University of Arizona, 1130 East Helen Street, McClelland Hall 430, P.O. Box 210108, Tucson, AZ, United States, Laura Brandimarte, Yinchu Zhu, Dong Jing

Negative feedback (e.g., downvotes) in online communities helps to control the quality of contribution but may discourage users from participation, especially for new users. In this paper, we conduct a randomized field experiment to evaluate the causal effect of downvotes on user-generated content. We find that downvotes indeed decrease future user contributions. However, this effect only exists for new users who have less experience. Instead, experienced users increase their contributions after negative feedback. Policy evaluation results using machine learning methods provide design suggestions for downvotes base on the characteristics of contributors.

#### 3 - Impact of the Interplay Between Review Volume and Rating in Digital Platforms on Sales: An Empirical Study

Samayita Guha, Temple University, Philadelphia, PA, United States, Naveen Kumar, Subodha Kumar, Joydeep Srivastava

Impact of the Interplay between Review Volume and Rating in Digital Platforms on Sales: An Empirical Study. Consumers now increasingly depend on user-generated reviews. Based on the data collected from a digital-platform, we empirically examine the impact of interaction between the number of reviews and the average rating. This study would help us in answering an important and relevant question: What is more important - Volume or Quality?

#### 4 - From Broadcasting to Narrowcasting: Examining User Content Consumption, Generation and Sharing in Social Media

Lanfei Shi, University of Maryland College Park, College Park, MD, United States

User engagement (UE) through content consumption (CC), content generation (CG) or content sharing (CS) on social media has been widely studied. However, the fundamental question of how the 3 dimensions of UE interact remains largely unanswered. Therefore, we design a large-scale randomized field experiment to investigate the causal effect of CC reduction on CG and subsequent CS on Snapchat. We are among the first to examine the interplay of different dimensions of UE using a randomized field experiment for causal inference. Our findings complement the current literature of user behavior on social sites and provide useful insights into platform design and marketing campaigns on social platforms.

## ■ MA68

West Bldg 105C

### IEEE Transactions on Automation Science and Engineering Invited Session

Sponsored: Quality, Statistics and Reliability

Sponsored Session

Chair: Jingshan Li, The University of Wisconsin-Madison

Co-Chair: Xiao Liu, University of Arkansas

#### 1 - Prescriptive Modeling and Compensation of In-plane Shape Deformation for 3D Printed Freeform Products

Qiang Huang, University of Southern California, Dept of Industrial & System Engineering, 3715 McClintock Avenue, Ger 240, Los Angeles, CA, 90089, United States, He Luan

The shape accuracy of 3D printed products is a critical issue, especially for freeform products with complex geometries. In addition, shape accuracy modeling has to be transparent to specific designs and 3D printing processes for wider applications. This study fills the gap by establishing a data-driven approach to predict and compensate the in-plane (x-y plane) shape deviations of 3D printed freeform products based on a limited number of simple trial shapes. Experimental investigation using stereolithography process successfully validates the proposed prescriptive approaches.

## 2 - A Wavelet-based Penalized Mixed-effects Model for Multichannel Profile Detection of In-line Raman Spectroscopy

Xiaowei Yue, Georgia Institute of Technology, 755 Ferst Drive NW, ISYE, Atlanta, GA, 30332, United States, Hao Yan, Jin Gyu Park, Richard Liang, Jianjun Shi

Modeling and analysis of high-dimensional (HD) profiles, is an important and challenging topic. We proposed a wavelet-based penalized mixed-effects decomposition (PMD) method for multichannel profile detection of in-line Raman spectra. The PMD exploits a regularized HD regression with linear constraints to decompose profiles into four parts: fixed effects, normal effects, defective effects, and noise. An APG optimization algorithm is developed for parameter estimation. Finally, extracted coefficients are associated with consistency, uniformity, and defects. In case study, we evaluated the performance of the PMD and demonstrated a better detection power with less computational time.

## 3 - Optimize the Signal Quality of the Composite Health Index via Data Fusion for Degradation Modeling and Prognostic Analysis

Abdallah A. Chehade, Assistant Professor, University of Michigan-Dearborn, 4901 Evergreen Road, 2280 HPEC, Dearborn, MI, 48128, United States

The rapid development of sensing and computing technologies enabled to simultaneously monitor different components of complex systems. This provided unprecedented opportunity to understand the degradation behavior of complex systems. In this paper, a signal-to-noise ratio (SNR) metric that is tailored to the needs of degradation signals is proposed. Then, based on the SNR metric, we develop a data-level fusion model to construct a health index via fusion of multiple degradation-based sensor data. Our goal is that the health index provides better estimates for the health condition and the remaining lifetime. A case study that involves the degradation dataset of aircraft gas turbine engines.

## 4 - Publication at IEEE T-ASE

Shiyu Zhou, University of Wisconsin-Madison, 3254 Mech Eng Bldg, 1513 University Avenue, Madison, WI, 53706-1572, United States

Abstract not available.

## 5 - Publication at IEEE T-ASE Part 1

Kaibo Liu, UW-Madison, 1513 University Avenue, Madison, WI, 53706, United States

Panel discussion of paper publication in IEEE T-ase journal

## ■ MA69

West Bldg 106A

## Degradation Test and Data Analysis

Sponsored: Quality, Statistics and Reliability

Sponsored Session

Chair: Rong Pan, Arizona State University, Tempe, AZ, 85287-8809, United States

Co-Chair: Guanqi Fang, Arizona State University, Tempe, AZ

## 1 - Bivariate Accelerated Degradation Modeling Based on Heterogeneous Marginal Stochastic Processes

Guanqi Fang, Arizona State University, 745 N. Dobson Rd, Unit 115, Mesa, AZ, 85201, United States

This presentation discusses a flexible modeling approach when dealing with bivariate degradation data. An example about application on polymer material is given to demonstrate the proposed modeling and data analysis flow.

## 2 - Predicting Lifetime by Degradation Tests: A Case Study of ISO 10995

Steve Rigdon, Saint Louis University, St. Louis, MO, 62026, United States

ISO 109951 is the international standard for the reliability testing and archival lifetime prediction of optical media. The standard specifies the testing conditions in terms of the combinations of stress variables - temperature and relative humidity. The standard assumes that the projected failure time is the actual failure time and these projected failure times are then analyzed. Since true failure times are not directly observed, the uncertainties in the failure time must be taken into account. In this paper, we present a hierarchical model for degradation that can directly infer failure time at the use condition and compare this model with the ISO standard through a simulation study. Not accounting for the uncertainty in the projected failure times leads to unjustified confidence in the estimation for the median lifetime at both the stress conditions used in the experiments and at the use condition.

## 3 - On Degradation Modeling Under Dynamic Environment

Xiao Liu, University of Arkansas, 4172 Bell Engineering Center, Fayetteville, AR, 72701, United States, Mohammad Mahdi Hajiha

This presentation discusses the modeling of degradation under dynamic environment. Application examples are presented to demonstrate the proposed modeling approach.

## ■ MA70

West Bldg 106B

## Joint Session QSR/DM: Machine Learning for Manufacturing Informatics

Sponsored: Quality, Statistics and Reliability

Sponsored Session

Chair: Hao Yan, Arizona State University, Tempe, AZ

## 1 - Robust Change Detection via Affine and Quadratic Detectors

Yao Xie, Georgia Institute of Technology, GA, United States, Yang Cao, Vincent Guigues, Anatoli Juditsky, Arkadi Nemirovski

Change-point detection is a fundamental problem in statistics and signal processing with applications in manufacture systems. Given a sequence of data, the goal is to detect any change in the underlying distribution as quickly as possible. However, classic approaches usually require exact specification of the pre- and post-change distributions forms, which may not perform well with real data. We present a set of computationally efficient methods with certain near optimality properties, which allow uncertainties about the pre-and post-change distribution, by building a connection of change-point detection with robust convex optimization.

## 2 - Online Anomaly Detection with Adaptive Sampling for Multivariate Streaming Data

Chen Zhang, National University of Singapore, E1-07-26, 3 Engineering Drive, Singapore, 117576, Singapore

This paper addresses online anomaly detection of a system with multivariate variables, when only a subset of variables can be observed at each sensing epoch. We first propose a weighted Bayesian estimation framework for system state estimation which can deal with missing variables. Then based on the confidence region of the estimated system state, an anomaly detection scheme is constructed by considering correlations of different variables. We formulate its detection power as a multi-armed bandit problem, and propose an adaptive sampling strategy using the upper confidence bound algorithm. With the proposed strategy, we further derive the asymptotic detection power of our scheme.

## 3 - Understanding the Effects of Predictor Variables in Black Box Supervised Learning Models

Jingyu Zhu, Northwestern University, Evanston, IL, United States, Daniel Apley

A shortcoming of many supervised learning models is their lack of interpretability and transparency, in terms of understanding how the predictor variables affect the response. Partial dependence plots are used for visualization but involve unreliable extrapolation when the predictors are highly correlated. We present a new visualization approach termed accumulated local effects (ALE) plots that avoid extrapolation like functional ANOVA but are far more computationally efficient. They also yield convenient variable importance measures for quantifying and ranking the impact of each predictor.

## 4 - Real-time Anomaly Detection for Spatial-temporal Correlated Profile

Hao Yan, 699 S. Mill Ave, Tempe, AZ, 85281, United States, Kamran Paynabar, Massimo Paccella

Advanced 3D metrology technologies such as Coordinate Measuring Machine (CMM) and laser 3D scanners have facilitated the collection of massive point cloud data, beneficial for process monitoring, control and optimization. However, due to their high dimensionality and structure complexity, modeling and analysis of point clouds are still a challenge. In this paper, we utilize multilinear algebra techniques and propose a set of tensor regression approaches to model the variational patterns of point clouds and to link them to process variables. The performance of the proposed methods is evaluated through simulations and a real case study of turning process optimization.

## ■ MA71

West Bldg 106C

### Joint Session ICS/ IOS Uncert: Adaptive/Sequential Sampling for Stochastic Programs

Sponsored: Computing

Sponsored Session

Chair: Yongjia Song, Clemson University, SC, 29634, United States

#### 1 - Variance Reduction in Sequential Sampling for Stochastic Programming

Jangho Park, PhD Candidate, The Ohio State University, 1971 Neil Avenue, Columbus, OH, 43210-1271, United States, Rebecca Stockbridge, Guzin Bayraksan

We investigate variance reduction techniques Latin Hypercube Sampling (LHS) and Antithetic Variates (AV) in sequential sampling for stochastic programming. Sequential sampling takes a sequence of solutions and assesses their quality by sequentially increased samples. We show conditions under which the procedures stop in a finite number of iterations and are valid. We computationally compare LHS and AV in sequential and non-sequential settings. Our results indicate that while both are effective, LHS dominates in the non-sequential setting and AV gains an advantage in the sequential setting.

#### 2 - Adaptive Sequential Sampling for Stochastic Programs

Yongjia Song, Clemson University, 211 Fernow Street, 264 Freeman Hall, Clemson, SC, 29634, United States, Raghu Pasupathy

In this talk, we propose a new sequential sampling approach that unifies existing literature on the sequential sampling approach and the retrospective approximation approach for solving stochastic programs. Specifically, we stipulate schedules of sample size used for solving each sample-path problem at each iteration as has been done in the sequential sampling literature. In addition, we choose optimality gap tolerance adaptively, making it a factor of the sample error corresponding to the current iterate in the sample-path problem. We show that these choices are optimal under a precisely defined criterion. Numerical results on two-stage stochastic linear programs will be reported.

#### 3 - Adaptive Sampling with Norm and Inner Product Tests for Smooth Stochastic Optimization

Raghu Pasupathy

We characterize the sample-path behavior of stochastic gradient descent (a.k.a. stochastic approximation). Such characterization leads naturally to adaptive sampling structures within stochastic gradient descent. We will discuss two specific variations of adaptive sampling SGD that use what has recently been called the norm test and inner product test, along with sample-path complexity results. Numerical results routinely demonstrate better practical performance while achieving sample-path convergence rates that are arbitrarily close to the best possible.

#### 4 - Stochastic Algorithms for Conditional Stochastic Optimization

Shuotao Diao, University of Southern California, Los Angeles, CA, 90007, United States, Suvrajeet Sen

Conditional stochastic optimization models arise when the uncertainties involve correlated latent random effects. This presentation discusses several algorithms based on first-order methods in the context of nonparametric regression (e.g. k-NN). We study the asymptotic convergence of these algorithms.

## ■ MA72

West Bldg 211A

### Joint Session Wagner/Practice: Daniel H. Wagner Prize for Excellence in Operations Research Practice

Emerging Topic: Daniel H. Wagner Competition

Emerging Topic Session

Chair: Patricia Neri, SAS Institute, Inc., 104 Grandtree Ct., Cary, NC, 27519, United States

#### 1 - Analytics and Bikes: Riding Tandem with Motivate to Improve Mobility

Daniel Freund, Cornell University, 109 Lake St, Ithaca, NY, 14850, United States, Shane Henderson, David B. Shmoys, Eoin O'Mahony

Bike-sharing systems are now ubiquitous across the U.S. We have worked with Motivate, the operator of the largest such systems, including in New York, Chicago and San Francisco, to innovate data-driven approaches for bike-sharing. With them we have developed methods to improve their day-to-day operations and also provide insight on central issues in the design of their systems. This work

required the development of a number of new optimization models, characterizing their mathematical structure, and using this insight in designing algorithms to solve them. In our presentation, we focus on two particularly high-impact projects, an initiative to improve the allocation of docks to stations, and the creation of an incentive scheme to crowdsource rebalancing. Both of these projects have been fully implemented to improve the performance of Motivate's systems across the country: Motivate has moved hundreds of docks in its systems nationwide and the Bike Angels program now aids rebalancing in San Francisco and NYC. In NYC, Bike Angels yields improvement comparable to that obtained through Motivate's traditional rebalancing efforts, at far less financial and environmental cost.

#### 2 - What's Wrong with My Dishwasher: Advanced Analytics Improve the Diagnostic Process for Miele Technicians

Segev Wasserkrug, IBM Haifa Research Lab, Haifa, 31905, Israel, Evgeny Shindin, Sergey Zeltyn, Martin Krueger, Yishai Feldman

Miele, a leading appliance manufacturer, is looking to optimize the ways in which they solve customer problems quickly and efficiently. A crucial part of this task is precise diagnosis of faults, before and during technician visits. A correct diagnosis allows technicians to take with them the necessary parts and complete the repair with a minimal spending of time, effort, and spare parts. We created a decision-support system to help Miele optimize its service process, based on statistics learned from historical data about technician visits, containing both structured and unstructured (textual) data that had to be combined to create the probabilistic model. We used a novel process in which a semantic model informed the creation of the probabilistic model, as well as the analysis pipelines for the structured and unstructured data, combining expert knowledge with large heterogeneous data. The results of a pilot study demonstrated a significant improvement of efficiency, concomitant with an increase of an already very high first-fix rate.

## ■ MA73

West Bldg 211B

### Crop Challenge

Emerging Topic: INFORMS Special Sessions

Emerging Topic Session

Chair: Chris Tutino, Syngenta, 9 Davis Drive, Research Triangle Park, NC, 27709, United States

#### 1 - Using Data Analytics to Help Improve Agriculture in the 2019 Syngenta Crop Challenge in Analytics

Greg Doonan, Syngenta, 2369 330 Street, Slater, IA, 50244, United States

The 2019 Syngenta Crop Challenge in Analytics is a collaborative effort between Syngenta and the INFORMS Analytics Society that brings together experts in mathematics, agriculture and big data to demonstrate how data can be used to feed a growing global population with limited natural resources. Join Greg Doonan, head of novel algorithm advancement at Syngenta, to learn how you can use your data analytics skills to help scientists develop better crops. This year's question asks participants to determine if corn hybrid performance data can be used to develop models that predict crop performance across a range of environmental scenarios. Understanding how a hybrid reacts to certain stresses can help breeders develop better seeds that allow farmers the potential to grow corn where they couldn't before. The contest is unique because Syngenta gives participants real-world, proprietary data to create their models. The contest is open and submissions will be accepted until Jan. 18, 2019. Finalists will be announced in March and will be invited to present their entries at the 2019 INFORMS Conference on Business Analytics & Operations Research April 14-18, 2019 in Austin, Texas. The winners will be announced during the event. The first place winner will be awarded \$5,000. Second place receives \$2,500 and third place will receive \$1,000.



## ■ MA74

West Bldg 212A

**Joint Session MCDM/Practice Curated: Multiobjective Optimization: Theory and Applications**

Sponsored: Multiple Criteria Decision Making

Sponsored Session

Chair: Margaret M. Wiecek, Clemson University, Clemson, SC, 29634-1907, United States

**1 - On Highly Robust Efficient Solutions for Uncertain Multiobjective Linear Programs**

Margaret M. Wiecek, Clemson University, Mathematical Sciences Dept, Clemson, SC, 29634-1907, United States

We develop properties of the highly robust efficient (HRE) solutions to uncertain multiobjective linear programs (UMOLPs) with objective-wise uncertainty in the objective function coefficients. A characterization using the cone of improving directions, several bound sets on the HRE set, and a robust counterpart for a class of UMOLPs are provided. A bilevel method for computing the HRE solutions is proposed.

**2 - Multiobjective Design of a Fin in a Steady-State Regime**

Lakmal Weerasena, University of Tennessee Chattanooga, 615 McCallie Ave, Chattanooga, TN, 37403, United States, Boris Belinskiy, James Hiestandzand.

Removal of waste heat to another material or the environment by convection and radiation is important in everyday life and industrial applications. Extended surfaces are often used to remove heat and such surface extensions for convective heat transfer frequently are called fins. The design of a fin is modeled as bi-objective optimization problem. The efficiency of the fin and its mass are considered as two objective functions and the multi-objective optimization carried out to maximize the efficiency and the minimize the mass simultaneously. The approach is based on a piece-wise constant design of the fin.

**3 - Balancing Mission Goals and Maintenance Demands using a Force Structure Model**

Chris Grubb, Systems Planning and Analysis, Inc., Alexandria, VA, United States, Stephanie Diane Brown, Jonathon Leverenz, Brian Chen

A Force Structure Model designs a day-to-day schedule for a set of assets to meet mission goals and maintenance demands while satisfying travel, duration, and operational constraints. Tension in the schedule arises from the desire to maximize time allotted for maintenance against the need to provide a sufficient number of assets for missions each day. A network-based model and branch-and-bound algorithm are used to investigate tradeoffs between allocating time for mission goals and maintenance demands. The network model offers more flexibility than existing timetabling methods when designing the schedule and the algorithm is shown to outperform CPLEX for longer, more difficult problems.

**4 - Multi-objective Optimization for Political Districting with Explicit Fairness Considerations**

Rahul Swamy, Champaign, IL, 61820, United States, Douglas M. King, Sheldon H. Jacobson

Political redistricting is a multi-objective problem with conflicting objectives such as compactness, population balance, etc. While the problem is well-studied, the use of political fairness metrics has been relatively under-explored. In addition, contiguity enforcement within an exact method has been a challenging task. This research presents a multi-objective approach explicitly considering political criteria such as efficiency gap and competitiveness within a branch and cut framework. The results show that compactness does not always ensure political fairness, and vice versa.

## ■ MA75

West Bldg 212B

**Joint Session MAS/Practice Curated: Advanced Analytics for Military Cyber Security, Defense and Readiness**

Joint Session

Chair: Nathaniel D. Bastian, PhD, Army Cyber Institute, West Point, NY, 10996, United States

**1 - Early Warning Systems for Cyber Security**

Isaac Faber, PhD Candidate, Stanford University, 141 Aryshire Farn Ln #113, Stanford, CA, 94305, United States

Through the paradigm of early warning systems, from risk analysis, early-stage cyber attack signals can be generated using machine learning techniques. The past ten years have seen the growth of interest in cybersecurity. As cyber threats become more sophisticated, system defenders must keep pace with better methods of detection and response. Advanced cyber-attacks are a set of discrete,

observable steps called a 'kill chain.' Using burgeoning techniques within analytic systems and machine learning, data produced from early kill chain steps can be used to mitigate downstream consequences. An application of ensemble classification using supervised learning techniques is explored.

**2 - Bots in Nets: Empirical Analysis of Bot Evidence in Online Social Networks**

Ross Schuchard, George Mason University, 4400 University Drive, Fairfax, VA, 22030, United States

Online social networks (OSNs) continue to play an increasing role as a primary source of information in today's society. The emergence of social bots within OSNs to diffuse information at scale has given rise to many efforts to detect bots. While methodologies employed to detect the evolving sophistication of bots continue to improve, much work can be done to characterize the impact of bots on actual communication networks. This study proposes a social network analysis framework to characterize the pervasiveness and relative importance of bots in various OSN conversations.

**3 - Fake News: Fearing the End of Truth, a Quantitative Risk Analysis**

Travis Trammell, Stanford University, Stanford, CA, United States

Strategically using information to affect the views of a population is certainly nothing new and dates all the way back to the earliest development of political systems. The speed of distribution and the number of people that can be reached by leveraging the modern information infrastructure is unprecedented. The rapid distribution of fake news can cause contagion, manipulate markets, spark conflict, or fracture strategic relations. Probabilistic Risk Analysis (PRA) can be leveraged to quantitatively describe the risk associated with fake news by examining all relevant factors to evaluate associated probabilities and costs resulting from fake news campaigns.

**4 - Saving the Army from Cyberspace: A Strategy to Seize the Initiative Using Big Data**

Gregory Bew, U.S. Army Cyber Command, Fort Belvoir, VA, United States

In the information age the defense of the Department of Defense Information Network (DoDIN) is arguably our most mission essential task. Mission command, logistics, medical support, and weapons systems all rely on access to the DoDIN or we will operate in a severely degraded state. In war, that means people will die. To ensure access, Army Cyber Command decided to rely on big data and developed a phased approach to seize initiative, increase confidence, and change our culture to defend our cyber terrain. The results of this approach have created the DoD's largest and most capable cyber big data platform, providing a common environment to develop apps and analytics to help the Army defend the DoDIN.

**5 - An Advanced Analytics Framework for Optimizing Army Cyber Mission Force Readiness and Manning**

Nathaniel D. Bastian, Operations Research Scientist, Army Cyber Institute, U.S. Military Academy, West Point, NY, 10996, United States, Andrew O. Hall, Christopher B. Fisher

Given the unique expertise required of military personnel to execute the DoD cyber mission, the US Army created the Cyber Branch to establish managed career fields for Army cyber warriors, while providing a force structure with successive opportunities for career development and talent management via leadership and broadening positions, technical training, and advanced education. In order to optimize Cyber Mission Force readiness and manning levels across the Army's operating and generating forces, we proffer the Cyber Force Manning Model (CFMM) to project the optimal number of accessions, promotions and personnel inventory for each cyber specialty across the Army cyber enterprise.

## ■ MA76

West Bldg 212C

**Production Logistics and Supply Chain**

General Session

Chair: Feng Ju, Arizona State University, Tempe, AZ, 85281, United States

Co-Chair: Feifan Wang, Arizona State University, Arizona State University, Tempe, AZ, 85281, United States

**1 - A Facility Location Problem with Inventory-level-dependent Hazard Zones**

Mina Aliakbari, Texas A&amp;M, College Station, TX, United States, Joseph Geunes

We consider a location problem for administrative facilities and hazardous stock. Each stock location creates an inventory-level-dependent hazard zone within which no administrative facilities may be located. Increasing the stock at a location increases the radius in which administrative offices are forbidden. We seek a set of administrative and stock locations that can accommodate required warehouse and office space at a minimum total cost. Such problems arise, for example, on military bases or in the production of hazardous materials. This results in a large-scale combinatorial optimization problem, for which we propose using Lagrangian relaxation and heuristic solution techniques.

### 3 - Performance Evaluation of Geometric Serial Lines with Residence Time Constraints

Feifan Wang, Arizona State University, 669 S. Mill Ave, Tempe, AZ, 85281, United States, Feng Ju

Residence time constraints are commonly required in production systems, where parts need to stay in each buffer for some time within a predefined range. Due to a large state space, the direct analysis of such production systems is difficult. To address this problem, we develop an approximate model for a two-machine-one-buffer sub-system. An aggregation method, which takes the sub-system as a building block, is proposed to obtain the performance measures of a multi-machine line. Numerical experiments suggest that the approximate method can capture the system performance in both transient and steady state.

### 4 - Real-time Scheduling of Complex Resource Allocation Systems through Fluid Relaxations

Spyros Reveliotis, Georgia Institute of Technology, 765 Ferst Drive ISyE, Atlanta, GA, 30332-0205, United States, Michael Ibrahim

This work addresses the problem of the efficient real-time management of resource allocation in complex workflows that involve blocking and deadlocking effects. To this end, we adapt to the considered problem setting the scheduling approach that is based on the formulation and solution of a pertinent “fluid relaxation” of the addressed operations. Our results are substantially empowered by our ability to develop efficient deadlock avoidance policies for the considered resource allocation, that take the form of linear inequalities imposed on the underlying system state. Extensive numerical experimentation reveals the operational and computational efficiency of the derived policies.

### 5 - An Introduction to Framework of Simulation Analytics for Real-time Optimal Decision on What-if Scenarios

Haobin Li, National University of Singapore, 1 Engineering Drive 2, Singapore, 117576, Singapore, Xiao Jin, Weizhi Liu, Chenhao Zhou, Loo Hay Lee, Ek Peng Chew

A concept of simulation that supports a real-time decision making has raised much attention in recent years. However, it remains unclear how to combine simulation with an online decision in a valid way. To categorize main issues and pave a way for a possible application, we propose a new framework, namely “Simulation Analytics” that can be treated as an interface between simulation and real-time decision process. We expect such a paradigm to be universal in the new era for simulation-based optimization. A literature study is first conducted followed by a demonstration of the full framework. A brief case study is attached at the end which hints a possible application under this frame.

## MA77

West Bldg 213A

### Location Models III

Sponsored: Location Analysis

Sponsored Session

Chair: Pawel J. Kalczynski, CSU-Fullerton, 800 N. State College Blvd., Fullerton, CA, 92834-6848, United States

#### 1 - Self-organized Carpools with Meeting Hubs

Pawel J. Kalczynski, California State University-Fullerton, 800 N. State College Blvd., Fullerton, CA, 92834-6848, United States, Malgorzata M. Miklas-Kalczynska

We incorporate optional meeting hubs into the original car pooling problem. A meeting hub is a common origin for all carpool participants. It may be one of the participants' origins or a chosen meeting point such as a plaza or gasoline station. We present a new heuristic, formulated and tested on real-world and simulated car pooling problem instances, that mimics a decentralized carpool self-organization process by allowing commuters to maximize their own savings. Our findings reveal system-wide savings similar to centralized models, and a potential strategy for improving carpool utilization.

#### 2 - Cooperative Cover of Uniform Demand

Zvi Drezner, California State University Fullerton, Steven G. Mihaylo College of Business and Economics, Dept of ISDS, Fullerton, CA, 92834, United States, Tammy Drezner

We investigate the total covered area by multiple facilities applying the cooperative cover model. The cooperative cover area is much larger than the one found by standard cover models. We also show that for a large number of facilities located in a symmetric grid, an hexagonal grid is best. We also investigated covering a given area by a given number of facilities, such as a square, with the weakest possible signal emitted by the facilities.

### 3 - A Voronoi Based Heuristic for the Planar Multiple Obnoxious Facilities Location Problem

Pawel J. Kalczynski, California State University-Fullerton, 800 N. State College Blvd., Fullerton, CA, 92834-6848, United States, Zvi Drezner, Said Salhi

Consider a situation in which a given number of facilities must be located in a convex polygon with the objective of maximizing the minimum distance between facilities and a given set of communities subject to the facilities being farther than a certain distance from one another. This continuous multiple obnoxious facility location problem is very difficult to solve by commercial nonlinear optimizers. We propose a mathematical formulation of two variants of the problem and a heuristic approach based on Voronoi diagrams and a binary linear program. We found that our results are much better and were obtained in a fraction of the time required by other popular state of the art solvers

### 4 - Advances in Competitive Facilities Models

Tammy Drezner, California State University Fullerton, 800 N. State College, Fullerton, CA, 92834, United States, Zvi Drezner, Dawit Zerom

Two improvements to the Huff gravity model are proposed and tested. 1) Assuming that facilities' attractiveness has a random distribution. Perception of facilities' attractiveness vary among customers. 2) Assuming different decay functions for different facilities. In existing models the distribution of demand by distance has the same shape. However, more attractive facilities attract customers from larger distances. The decline in patronage is slower than the decline for less attractive facilities.

## MA78

West Bldg 213B

### Joint Session PSOR/SOLA: Location Models for Social Good

Sponsored: Location Analysis

Sponsored Session

Chair: Kayse Lee Maass, Northeastern University, 360 Huntington Ave, Boston, MA, 02115, United States

#### 1 - Using Spatial Data Analytics to Identify Associations Between Home Healthcare Accessibility and Socioeconomic Factors

Ashlea Bennett Milburn, University of Arkansas, 4207 Bell Engineering Center, Fayetteville, AR, 72701, United States, Jessica Heier Stamm, Mehmet Serdar Kilinc

Home healthcare can improve health outcomes and reduce healthcare costs, but only if the service is accessible. We use healthcare system and socioeconomic data to fit space-varying coefficient models, from which we make inference about spatially explicit relationships between home healthcare accessibility and socioeconomic factors including rural/urban status, income, and race/ethnicity. We find statistically significant and spatially varying relationships at the ZIP Code level in Arkansas. Our results suggest policies to address disparities and improve outcomes.

#### 2 - Human trafficking: Barriers of Using Supply Chain Methodologies/Interdiction Models to Disrupt Illicit Supply Chains of Human Traffickers

Felipe Aros-Vera, Ohio University, 277 Stocker Center, 1 Ohio University, Athens, OH, 45701, United States, Cami Jones, Alana Weszelits

Human trafficking, specifically sex trafficking, is a form of modern day slavery that is occurring on a global scale and continues to gain foothold in the United States. This presentation maps the similarities of the sex trafficking supply chain to a standard supply chain framework and propose useful metrics specific to the sex trafficking supply chain. The main objective of this work is to provide foundational basis for future quantitative analysis on interdiction models to cripple sex traffic supply chains.

#### 3 - A Broader Perspective: Integrating Societal Factors Into Human Trafficking Shelter Location Models

Kayse Lee Maass, Assistant Professor, Northeastern University, Boston, MA, United States, Renata Alexandra Konrad, Andrew C. Trapp

Rehabilitative shelters play a critical role in the safety, stabilization, and long term recovery of human trafficking survivors. Yet, in every U.S. state the demand for such shelters greatly exceeds the current capacity, and the lack of available, reliable data poses a challenge to human trafficking modeling. Using concepts from health and social welfare economics, we develop a decision analytic approach to maximize the societal value of locating additional shelters at the state level under budget constraints. We discuss our methods for quantifying societal factors and illustrate how the optimal placement of shelters is affected by changes to the budget, shelter costs, and societal benefits.

## Monday, 10:00AM - 10:50AM

### ■ Plenary

West Bldg 301AB

#### Plenary: Learning in Games (Philip McCord Morse Lecture)

Plenary Session

Chair: Margaret L. Brandeau, Stanford University, Management Science and Engineering, 475 Via Ortega, Stanford, CA, 94305-4026, United States

##### 1 - Learning in Games

Eva Tardos, Cornell University, Ithaca, NY, United States

Selfish behavior can often lead to suboptimal outcome for all participants, a phenomenon illustrated by many classical examples in game theory. Over the last decade we developed good understanding on how to quantify the impact of strategic user behavior on the overall performance in many games (including traffic routing as well as online auctions). In this talk we will focus on games where players use a form of learning that helps them adapt to the environment, and consider two closely related questions: What are broad classes of learning behaviors that guarantee high social welfare in games, and are these results robust to situations when game or the population of players is dynamically changing.

## Monday, 11:00AM - 12:30PM

### ■ MB01

North Bldg 121A

#### Chance Constrained Optimization

Sponsored: Optimization/Optimization Under Uncertainty

Sponsored Session

Chair: Bismark Singh, Sandia National Laboratories, Albuquerque, NM, 87185, United States

##### 1 - Approximating Two-Stage Chance-Constrained Programs with Classical Probability Bounds

Bismark Singh, Sandia National Laboratories, P.O. Box 5800, MS 1326, Albuquerque, NM, 87185, United States, Jean-Paul Watson

We consider a joint-chance constraint (JCC) as a union of events, and approximate this union using bounds from classical probability theory. When these bounds are used in an optimization model constrained by the JCC, we obtain corresponding upper and lower bounds on the optimal objective function value. We investigate the strength of these bounds under two different sampling schemes, and observe that a larger correlation between the uncertainties results in a more computationally challenging optimization model.

##### 2 - A Sigmoidal Approximation for Chance Constrained Nonlinear Programs

Yankai Cao, University of Wisconsin-Madison, 2011 Engineering Hall, 1415 Engineering Drive, Madison, WI, 53706, United States, Victor M. Zavala

We propose a sigmoidal approximation for the value-at-risk and we use this approximation to tackle nonlinear programs with chance constraints. We prove that the approximation is conservative and that the level of conservatism can be made arbitrarily small for limiting parameter values. We establish explicit connections between SigVaR and other approximations reported in the literature. A key benefit of SigVaR is that one can establish an explicit connection with the conditional value at risk approximation and exploit this connection to obtain initial guesses for the approximation parameters. We present small- and large-scale numerical studies to illustrate the developments.

##### 3 - Chance Constrained Optimization Based Solar Microgrid Design and Dispatch for Radial Distribution Networks

Hossein Dashti, University of Arizona, Tucson, AZ, United States, Jianqiang Cheng, Pavlo A. Krokhmal

We propose a two-stage model for optimal placement and planning of distribution generation (DG) and energy storage system units. We incorporate time series modeling to characterize the solar irradiance uncertainty. Design (location and sizing of DGs) and dispatch decisions (how much to generate and store) are made such that electricity demand is met reliably and cost effectively. We employ chance constraints to control the real load shedding within a predefined probability. We combine sample average approximation (SAA) and linearization techniques to solve the problem. Finally, we conduct an out-of-sample simulation on a case study in Arizona to assess the effectiveness of our approach.

##### 4 - On a Class of Chance-constrained Nonlinear Programming Problems

Belleh Fontem, University of Mary Washington, Fredericksburg, VA, United States, Jeremiah Smith

We consider the non-convex problem of minimizing a linear deterministic cost objective subject to a probabilistic requirement on a nonlinear multivariate stochastic expression attaining, or exceeding a given threshold. The stochastic expression represents the output of a noisy system featuring the product of mutually-uncorrelated, uniform random parameters each raised to a linear function of one of the decision vector's constituent variables. We prove a connection to (i) the probability measure on the superposition of a finite collection of uncorrelated exponential random variables, and (ii) an entropy-like affine function. Numerical experiments shed light on several model properties.

### ■ MB02

North Bldg 121B

#### Optimization under Multistage Uncertainty

Sponsored: Optimization/Optimization Under Uncertainty

Sponsored Session

Chair: Beste Basciftci, Georgia Institute of Technology, Atlanta, GA, 30332, United States

##### 1 - Matheuristic Algorithms for Multistage Location-assignment Problems under Uncertainty

Araceli Garin, Ph. Dr., University of the Basque Country, Bilbao (Bizkaia), 48015, Spain, Laureano Fernando Escudero, Celeste Pizarro, Aitziber Unzueta

We present two matheuristic procedures to build good feasible solutions (frequently, the optimal one) by considering the solutions of relaxed problems of large-sized instances of the multi-period stochastic pure 0-1 location-assignment problem. Additionally, for both procedures, a lazy heuristic scheme, based on scenario clustering, is considered for obtaining a feasible solution as an upper bound of the solution value of the full problem. Then, the same framework provides for the two procedures lower and upper bounds on the solution value. A broad computational experience is reported for 14 instances, up to 15 facilities, 75 customers, 6 periods, over 260 scenarios in the scenario tree.

##### 2 - On the Value of Multistage Stochastic Facility Location with (or without) Risk Aversion

Xian Yu, University of Michigan, Shabbir Ahmed, Siqian Shen

We consider facility location over a finite time horizon with uncertain demand. Comparing to a two-stage approach, we formulate a multistage stochastic integer program using scenario tree, to dynamically locate facilities at each period. We examine an expectation-based risk-neutral model and a risk-averse variant based on coherent risk measure. We show that the gaps between optimal objective values of the two multistage models and their two-stage counterparts are bounded from below, and the bound with risk aversion is at least as large as the risk-neutral bound. We also develop algorithms using SDDiP for solving both multistage models and demonstrate the computational efficiency.

##### 3 - Adaptive Two-stage Stochastic Programming

Beste Basciftci, Georgia Institute of Technology, H. Milton Stewart School, 755 Ferst Drive NW, Atlanta, GA, 30332, United States, Shabbir Ahmed, Nagi Gebraeel

In this study, we propose a novel adaptive stochastic programming approach, in which the best time to realize the uncertainty is a decision variable. Our approach can be considered as an approximation to multi-stage stochastic programming where the decision maker is not allowed to revise the decisions in each stage due to the problem restrictions. We provide theoretical bounds on the performance of the proposed approach compared to two-stage and multi-stage programs. We also propose algorithms for efficiently solving the resulting optimization model. In order to illustrate our results, we study various cases demonstrating the advantages of the adaptive two-stage approach.



## ■ MB03

North Bldg 121C

### TIMES Doctoral Dissertation Award

Sponsored: Technology, Innovation Management & Entrepreneurship

Sponsored Session

Chair: Jeremy Hutchison-Krupat, University of Virginia, University of Virginia, Charlottesville, VA, 22901, United States

#### 1 - Award Presenter

Tristan Botelho, Yale University, New Haven, CT, USA.

#### 2 - Three Essays on the Behavioral Foundations of Entrepreneurial Entry

Cedric Gutierrez Moreno, Bocconi University, Milano, Italy.

#### 3 - How to Improve Innovation Success: Customers, Employees, and the Search Process

Philipp Benjamin Cornelijs, Rotterdam School of Management, Rotterdam, Netherlands.

#### 4 - Incentive Design of On-Demand Marketplaces for Service and Innovation

Konstantinos Stouras, University of Virginia, The Darden School, Charlottesville, VA, USA

#### 5 - Designing Internal Innovation Contests

Lakshminarayana Nittala, University of Dayton, Dayton, OH, USA, Sanjiv Erat, Vish Krishnan

Firms can use internal contests to source solutions to problems associated with innovation. However, designing such contests involves nuanced understanding of the impact of such contests on the on-going projects within the firm. Optimal contest design is discussed along with managerial implications.

## ■ MB04

North Bldg 122A

### Advances in IPCO

Sponsored: Optimization/Integer and Discrete Optimization

Sponsored Session

Chair: Robert Hildebrand, Virginia Tech, VA, United States

#### 1 - Short Construction for Bounded Pitch Inequalities for Set Covering and Minimum-knapsack Problems

Daniel Bienstock, Columbia University, Dept of IEOR, 342 Mudd, New York, NY, 10027, United States

It is known that all undominated, nontrivial valid inequalities for a set covering problem are of the form  $a^T x \geq b$ , where  $a \geq 0$  and  $b > 0$ . Such an inequality is said to be of pitch  $k$  if the sum of the  $k$  smallest positive  $a_i$  is at least  $b$ , and  $k$  is smallest with regards to this property. In previous work, Bienstock and Zuckerberg described a compact extended relaxation for set covering problems that is guaranteed to satisfy all valid pitch  $\leq k$  inequalities, for each fixed  $k$ . As a corollary, for any fixed  $p > 0$  the rank- $p$  Gomory closure of a set covering problem can be approximately optimized over, for any fixed  $p$ . In this talk we consider minimum knapsack problems, which are implicitly set covering problems, albeit with an exponential number of covering constraints. We show that for any fixed integer  $k > 0$ , there is polynomial-time near-separation routine for the relaxation provided by all valid inequalities with coefficients in  $\{0, 1, 2, \dots, k\}$ . We discuss extensions and related problems. Joint work with Y. Faenza, I. Malinovic, M. Mastroilli, O. Svensson and M. Zuckerberg.

#### 2 - Algorithms and Results for Multi-row Group Problems

Robert Hildebrand, Virginia Tech, 223 Durham Hall, 1145 Perry St, Blacksburg, VA, 24061, United States

We study the 2-dimensional Infinite Group Problem and valid cut generating functions. We report on results and algorithms related to understanding these functions and determining their relative strength.

#### 3 - Assessing Parametrized Linear Programming Relaxations with Superadditive Duality

Temitayo Ajayi, Rice University, 2825 Bellefontaine Street #246A, Houston, TX, 77025, United States, Christopher Thomas, Andrew J. Schaefer

The integer programming gap is a foundational concept in optimization. Because linear programming relaxations are vital in most integer programming algorithms, it is important to assess the accuracy of linear programs as approximations of integer programs. Studies on gap functions over the past half-century either use abstract algebraic techniques or do not provide exact bounds. We present superadditive dual-based formulations to compute various metrics of model quality based on gap functions. Our formulations evaluate families of models parametrized by right-hand sides from discrete sets or hyper-rectangles.

#### 4 - The Subadditive Dual is a Strong Dual

Diego Moran, Universidad Adolfo Ibañez, Santiago, 24060, Chile

The subadditive dual of a conic mixed-integer program is a strong dual under a mixed-integer strict feasibility condition in the general case and rationality of the data in the linear case. In this talk, we present other sufficient conditions for strong duality. In particular, we show that strong duality holds if either the dual of the continuous relaxation or the subadditive dual are feasible. Moreover, we show that all known conditions imply dual feasibility. Finally, we present some duality results that use the concept of generator subadditive functions introduced by Klabjan (2007).

## ■ MB05

North Bldg 122B

### Conic Optimization in Machine Learning I

Sponsored: Optimization/Linear and Conic Optimization

Sponsored Session

Chair: Xudong Li, Princeton University, Princeton, NJ, United States

#### 1 - A Fast Globally Linearly Convergent Algorithm for the Computation of Wasserstein Barycenters

Lei Yang, National University of Singapore, Singapore, Singapore, Jia Li, Defeng Sun, Kim-Chuan Toh

In this paper, we consider computing a Wasserstein barycenter for a set of discrete distributions with finite supports. When the supports in the barycenter are prespecified, this problem can be modeled as a large-scale linear programming (LP). To solve this LP, we derive its dual problem and adapt a symmetric Gauss-Seidel based ADMM. We then analyze its global convergence and its global linear convergence rate without any condition. All subproblems involved can be solved exactly and efficiently. This makes our method suitable for large datasets. Numerical experiments on synthetic dataset and image dataset show that our method is more efficient than two existing representative methods and Gurobi.

#### 2 - Multi-level Stochastic Gradient Methods for Nested Composition Optimization

Shuoguang Yang, Columbia University, 500 West 120th Street, Room 315, New York, NY, 10027, United States, Mengdi Wang, Ethan Xingyuan Fang

Stochastic gradient methods are scalable for solving large-scale optimization problems that involve empirical expectations of loss functions. Existing results mainly apply to optimization problems where the objectives are one- or two-level expectations. We propose a class of multi-level stochastic gradient methods that are motivated from the method of multi-timescale stochastic approximation.

#### 3 - Fully Decentralized Multi-Agent Reinforcement Learning with Networked Agents

Zhuoran Yang, Princeton University, NJ, United States, Zhuoran Yang, Princeton University, Princeton, NJ, 08544, United States

We consider the problem of fully decentralized multi-agent reinforcement learning (MARL), where the agents are located at the nodes of a time-varying communication network. For this problem, we propose two decentralized actor-critic algorithms with function approximation, which are applicable to large-scale MARL problems where both the number of states and the number of agents are massively large. Our algorithms are fully incremental and can be implemented in an online fashion. Convergence analyses of the algorithms are provided when the value functions are approximated within the class of linear functions.

#### 4 - Geometry and Algorithms for Sparse Blind Deconvolution

Yuqian Zhang, Columbia University, New York, NY, United States, Han-Wen Kuo, John Wright

Blind deconvolution aims to recover a convolution kernel and an activation signal from their convolution. This talk focuses on the “short and sparse” variant, where the convolution kernel is short, and the activation signal is sparsely and randomly supported. We assume the kernel to have unit Frobenius norm, and formulate it as a nonconvex optimization problem over the sphere. By analyzing the optimization landscape, we argue that when the activation signal is sufficiently sparse, then on a region of the sphere, every local minimum is close to some shift truncation of the kernel. This geometric characterization implies that efficient methods obtain the ground truth under the same conditions.

### 5 - QSDPNAL: A Two-phase Augmented Lagrangian Method for Convex Quadratic Semidefinite Programming

Xudong Li, Princeton University, NJ, United States, Defeng Sun, Kim-Chuan Toh

In machine learning, statistics, and other areas, numerous interesting problems can be modeled in the form of convex composite quadratic conic programming. In this talk, we use the convex quadratic semidefinite programming (QSDP) problem as an example to introduce a two-phase augmented Lagrangian method (ALM), called QSDPNAL, for solving QSDP with linear equality and inequality constraints. Under mild conditions, we are able to establish the rate of convergence of the proposed algorithm and prove the R-(super)linear convergence of the KKT residual. Extensive numerical results show that our algorithm is highly efficient and robust in obtaining accurate solutions.

### ■ MB06

North Bldg 122C

### Optimization and System Analysis

Sponsored: Optimization/Computational Optimization and Software  
Sponsored Session

Chair: Les Servi, The MITRE Corporation, Bedford, MA, 01730-1420, United States

#### 1 - Comparison of Solution Methods in Evaluating a System of Risk Assessments

Mark Gallagher, Air Force, Washington, DC, United States, John Lepird, Daniel Fenn, Shane Hall

Military operations are a synthesis of capabilities, challenging integrated risk assessment. We establish a framework to integrate capabilities using a common risk metric, proposing a novel approach to establishing relationships between them, and deriving models aggregating risks and dependencies. This framework has informed billions of dollars of Air Force investments.

#### 2 - Offensive and Defensive Naval Weapon Assignment to Swarming Threats

Connor S. McLemore, Navy, Washington, DC, United States

We propose an automated decision aid capable of generating offensive and defensive engagement profiles for naval weapons. It allows the efficient pairing of multiple weapon systems to multiple swarming threats operating in multiple domains by providing the operator with recommended weapon-target pairings based on current capabilities and threat profiles. The model consists of pre-processing algorithms and reward-based mixed-integer programming models that takes as inputs the available weapon system capabilities and target information and outputs a recommended engagement profile.

#### 3 - A System-of-Systems Methodology for Analysis of the Behavior of Complex System

Dan DeLaurentis, Purdue University, West Lafayette, IN, United States, Cesare Guariniello

System Operational Dependency Analysis (SODA) is a methodology to assess the effect of dependencies between constituent elements of complex systems. The analysis, based on a parametric model of the behavior of the elements, is domain-agnostic and provides identification of critical areas, study of cascading effect of disruptions, and assessment of features of the whole system, such as robustness and resilience. SODA can be used to compare different systems architecture for decisions in early design phase, and to assess vulnerabilities and potential improvements of existing architectures.

#### 4 - Mission Dependency Analysis with Physical Network Relationship

Les Servi, The MITRE Corporation, M/S M230, 202 Burlington Road, Bedford, MA, 01730-1420, United States

A functional dependency network is a useful framework to evaluate alternative decisions under a constrained budget. It captures the impact of decisions on the hierarchy of goals and sub-goals required to achieve a mission. Motivated by cyber security considerations, this talk will describe the use of mixed integer linear programming to optimize the defending or attacking such networks but also taking into account the physical network associated with the functional network.

### ■ MB07

North Bldg 123

### Approaches in Security Problems

Sponsored: Optimization/Network Optimization  
Sponsored Session

Chair: N. Orkun Baycik, Shenandoah University, Winchester, VA, n/a, United States

#### 1 - Computing the Vulnerability of Multi-hop Wireless Networks: A Search for the $\delta$ Best Interference Model

Hugh Medal, Mississippi State University, P.O. Box 9542, MSU, MS, 39762, United States, Randy K. Buchanan

This paper studies the problem of placing a set of jammers in 3-D space in order to minimize the throughput of a wireless communication network. The main goal of this paper is to study the effects of jamming under several different models of interference (e.g., physical, capture, protocol, interference range). Toward this end, this paper presents a mixed-integer programming (MIP) formulation and branch-and-cut procedure for the jammer location problem under several models of interference as well as a study of the effect of different interference models on runtime and solution tractability.

#### 2 - Fishing and Trafficked Labor: An Examination of Policies to Address the Intersection of Prosperity and Exploitation

Renata Alexandra Konrad, Worcester Polytechnic Institute, School of Business, 100 Institute Road, Worcester, MA, 01609, United States, Khalid Saeed, Matt Kammer-Kerwick

Human exploitation in the seafood industry is a complex transnational problem jeopardizing human rights and marine ecosystems. Labor trafficking, environmental sustainability, aquaculture, and socio-economic development interact interdependently, and form a large system with multiple decision makers with conflicting goals. We present the results of a System Dynamics simulation model which incorporates resource management of fish stocks and illicit labor markets. Using this model, we examine the implications on trafficked labor of several policies including: imposing an excise tax, trafficking prevention campaigns, and increased policing.

#### 3 - Interdicting Layered Physical and Information Flow Networks

N. Orkun Baycik, Shenandoah University, Winchester, VA, United States, Thomas Sharkey, Chase Rainwater

We focus on the problem of interdicting layered networks that involve a physical flow network and an information flow network. There are interdependencies between the networks which leads to a network interdiction problem with a discrete inner problem. The objective of the defender is to send the maximum amount of flow through its physical flow network whereas the attacker seeks to minimize this maximum flow. For the case where the information supply arcs are uncapacitated, we apply a multi-step, dual-based reformulation technique. We apply this technique to law enforcement efforts against illegal drug trafficking and cyber vulnerability analysis of infrastructure networks.

### ■ MB08

North Bldg 124A

### Connectivity and Networks

Sponsored: Optimization/Network Optimization  
Sponsored Session

Chair: Hosseinali Salemi, Oklahoma State University, Stillwater, OK, 74075, United States

#### 1 - Connectivity and Power Domination in Graphs

Logan Smith, Graduate Student, Rice University, Houston, TX, United States

Power domination is related to the placements of sensors in electrical networks. Minimum power dominating sets in a graph correspond to minimal sensor arrays that are able to fully observe a given power grid. Nearby sensors can be supported with reduced infrastructure, thereby incentivizing the identification of minimum power dominating sets with induced subgraphs having a minimum number of components. Methods in power domination and connectivity constraints are adapted to solve this problem and computational experiments compare runtime performances.

#### 2 - A Lagrangian Relaxation Upper Bound on Clique Number of Graphs

Seyedmohammadhossein Hosseini, Texas A&M University, 3131 TAMU, College Station, TX, 77843-3131, United States, Sergiy Butenko

We introduce a new analytic (i.e., closed-form) upper bound on clique number of graphs. This bound is derived from a Lagrangian relaxation of an integer (linear) programming formulation of the maximum edge weight clique problem, and is characterized by degrees of vertices in the graph. We compare this bound with other analytic bounds proposed in the literature.

**3 - The Weighted Target Set Selection Problem on Cycles**

Rui Zhang, Assistant Professor, University of Colorado Boulder, Boulder, CO, 80309, United States, Subramanian Raghavan

The study of viral marketing strategies on social networks has become an area of significant research interest. In this setting, we consider the weighted target set selection (WTSS) problem. Motivated by the desire to develop a better understanding of fundamental problems in social network analytics, we focus on a special case where the underlying graphs are cycles. First, we propose a linear time algorithm for the WTSS problem on cycles. More importantly, we present a tight formulation in the node space. It provides a complete description of this polytope. Our work can be a building block for developing exact methods for tackling this important problem in social network analytics.

**4 - A Shortest Path Interdiction Problem with Improvement**

Timothy Holzmman, Clemson University, Engineering, Computing and Applied Sciences, Freeman Hall, Clemson, SC, 29634, United States, Cole Smith

We consider a shortest path interdiction problem with improvement. As in standard interdiction problems a leader and a follower play a Stackelberg game, wherein the leader seeks to maximize the follower's shortest path between two nodes on a graph. In our variant, in addition to the leader raising edge costs with a budget, the follower also has an opportunity to lower costs within a budget. We employ a multiobjective optimization model for problem where the leader is uncertain of the follower's budget. We present two solution methods and consider their comparative strengths and weaknesses.

**5 - New Integer Programming Formulations for Detecting Critical Nodes**

Hosseinali Salemi, Oklahoma State University, 15 North University Place, Apartment Number 2, Stillwater, OK, 74075, United States, Austin Buchanan

Recently, researchers have studied the problem of identifying so-called "critical nodes in networks, which are small subsets of nodes whose deletion maximally deteriorates a network. In this talk, we consider variants of this problem in which the task is to delete at most  $B$  nodes so as to minimize the number of node pairs that remain connected by: (1) a path, or (2) a path of length at most  $k$ . We propose new cut-like IP formulations for these problems and compare with previous approaches.

**■ MB09**

North Bldg 124B

**Intersections of Optimization and Statistical Learning**

Sponsored: Optimization/Nonlinear Programming

Sponsored Session

Chair: Sam Davanloo Tajbakhsh, The Ohio State University, Columbus, OH, 43210, United States

**1 - Rank Minimization Based Sparse Data Reconstruction in Sensory Networks**

Constantino Lagoa, PSU, State College, PA, United States, Ashkan Jasour

In this work, a novel approach to reconstruct a noisy sparse  $n$ -dimensional data is proposed. The main idea is to complete the data with least possible complexity. The complexity is defined as the number of exponential signals that could describe the data. We show that the number of exponential signals corresponds to the rank of block Hankel matrix constructed from given data. In this context, the problem of data reconstruction can be reformulated as matrix completion and rank minimization problems where the nuclear norm is used as a convex relaxation of the matrix rank. A first-order augmented Lagrangian algorithm is implemented for solving the resulting optimization problem.

**2 - On Stochastic Quasi Newton Methods for Illposed Stochastic Optimization Problems**

Farzad Yousefian, Oklahoma State University, 317D Engineering North, School of Industrial Engineering & Management, Stil, OK, 74074, United States, Angelia Nedich, Uday Shanbhag

We consider stochastic quasi-Newton (SQN) methods for solving unconstrained convex optimization problems. Much of the convergence analysis of SQN methods, in both full and limited-memory regimes, requires the objective function to be strongly convex and have Lipschitzian gradients. We develop SQN methods addressing absence of these assumptions. Particularly, we develop a regularized stochastic limited-memory BFGS algorithm, where the stepsize, regularization parameter, and the Hessian inverse approximate are updated iteratively. We establish convergence of the iterates to an optimal solution of the original problem. A convergence rate is derived in terms of the objective function.

**3 - Hierarchical Sparse Modeling**

Jacob Bien, University of Southern California, Los Angeles, CA, United States

It is common in statistics to demand sparsity patterns honoring certain problem-specific constraints. In hierarchical sparse modeling (HSM), these constraints specify that one set of parameters be set to zero whenever another is set to zero. Numerous papers have developed convex regularizers for this sparsity structure, which arises in many areas of statistics including interaction modeling and covariance estimation. We observe that these methods are based on two different types of group lasso that have not been systematically compared in the context of HSM. We investigate the differences both in terms of statistical properties and computational efficiency. Joint work with Xiaohan Yan.

**4 - Distributed Proximal Algorithms for Statistical Learning with Structured Sparsity**

Sam Davanloo Tajbakhsh, The Ohio State University, 210 Baker Systems Building, 1971 Neil Ave, Columbus, OH, 43210, United States

In some sparse statistical learning problems, solutions should follow sparsity structures between variables known a priori. Being able to generate such structures helps to obtain more interpretable models. Our study focuses on hierarchical sparsity structures represented as Directed Acyclic Graphs. Designed penalty functions exploit group overlaps to induce solutions with desired hierarchical structures. In this talk, we will present new distributed proximal algorithms to solve the underlying optimization problems with theoretical convergence guarantees. Some numerical results supporting the proposed algorithms will be provided.

**■ MB10**

North Bldg 125A

**On-demand Service Platforms**

Sponsored: Manufacturing & Service Oper Mgmt

Sponsored Session

Chair: Kaitlin Daniels, Washington University

**1 - Labor Welfare in On-demand Service Platforms**

Saif Benjaafar, University of Minnesota, 111 Church Street SE, Department of Industrial and Systems Engr, Minneapolis, MN, 55419, United States, Jian-Ya Ding, Guangwen Kong, Terry Taylor

We study labor welfare in on-demand service platforms that rely on independent agents. The platform chooses wages and prices knowing that customers are sensitive to both price and delay. In contrast to settings where customers are insensitive to delay, we show that an increase in labor supply does not necessarily result in lower wages and lower labor welfare.

**2 - Competition of On-demand Platforms**

Ming Hu, University of Toronto, Rotman School of Management, 105 St. George Street, Toronto, ON, M5S 3E6, Canada, Yan Liu

We study competition of on-demand platforms, where firms compete on both supply and demand sides. We consider various modes of competition, and study their implications on platforms' profit, prices on the demand side, wages on the supply side, and matching quantities at equilibrium. We also establish Kreps-Scheinkman equivalence in this type of two-sided markets.

**3 - Peak-period Pricing Strategies in the Presence of Customer Impatience and Store and Time Flexibility**

Steve Yoo, University College London, London, United Kingdom, Christopher S. Tang

Should a service firm charge higher prices during peak periods? We examine this question formally by analyzing a stylized duopoly model where firms compete for homogeneously impatient consumers. We consider four settings, defined by whether consumers are (i) flexible in their choice of store (where) and/or (ii) flexible in their choice of shopping time (when). For each setting, we use the concept of a rational expectation equilibrium to characterize how consumers endogenously segment themselves regarding where and when to shop to avoid congestion. We examine how the firms can profitably influence consumers' self-segmentation process by employing the peak-period pricing strategy.

**4 - Rewarding Loyalty: Bonus Design on Ridesharing Platforms**

Puping Jiang, Olin Business School, Washington University in St. Louis, Washington University Olin Business School, Knight Hall, Campus Box 1156, Saint Louis, MO, 63130-4899, United States, Kaitlin Daniels, Fuqiang Zhang

Ridesharing platforms commonly offer drivers a bonus payment that is contingent on the number of rides completed. The bonus constitutes a costly incentive that encourages drivers to drive exclusively for one platform. In this paper, we explain the existence of bonuses in the context of competing platforms and describe the market conditions that lead to their use.



## ■ MB11

North Bldg 125B

**Emerging Topics in Supply Chain Finance**

Sponsored: Manufacturing &amp; Service Oper Mgmt/iFORM

Sponsored Session

Chair: Panos Kouvelis, Washington University in St. Louis, Saint Louis, MO, 63130-4899, United States

Co-Chair: Fasheng Xu, Washington University in St. Louis, Saint Louis, MO, 63130, United States

**1 - Cancelability in Trade Credit Insurance**

Christopher J. Chen, London Business School, Regent's Park, London, NW14SA, United Kingdom, S. Alex Yang, Nitin Bakshi

Trade credit insurance (TCI) is a risk management tool commonly used by suppliers to guarantee against payment default by buyers. Unlike insurance policies in other sectors, TCI policies often allow the insurer to cancel this guarantee during the insured period. This paper explores the role of cancelability in TCI and its operational implications.

**2 - Risk-neutral or Risk-averse? An Empirical Study of Managed Print Services**

Jie Ning, Case Western Reserve University, Department of Operations, 328 Peter B. Lewis Building, Cleveland, OH, 44106, United States, Volodymyr O. Babich, John Handley, Jussi Keppo

We study the risk attitude of a service provider in the context of Managed Print Service (MPS), a type of business-to-business (B2B) service. We develop a hierarchical game theoretic model with asymmetric information to capture the contracting features of MPS. Using a proprietary data set from Xerox, we estimate Xerox's risk-aversion parameter using a structural approach and find empirical evidence that Xerox is risk-averse. We offer a new explanation for this result.

**3 - What Operations Management Researchers Should Know About Blockchain Technology**

Volodymyr O. Babich, Georgetown University, 37th & O. St NW, McDonough School of Business, Washington, DC, 20057, United States, Gilles Hilary

We examine the Blockchain technology's implications for operations management (OM). After briefly reviewing the technical foundations, we explore multiple business and policy aspects. Blockchain technology has emerged through the appearance of crypto-currencies. This may have been of limited interest to OM. The technology has now evolved beyond these markets and has started to offer the possibility to execute "smart contracts." This has immediate implications for the improvement of production and distribution networks. We identify five key advantages, five main drawbacks, and three themes associated with the Blockchain technology as it is applied to OM.

**4 - A Supply Chain Theory of Factoring and Reverse Factoring**

Fasheng Xu, Washington University in St. Louis, Campus Box 1156 One Brookings Drive, KH401, PhD Suite, Saint Louis, MO, 63130, United States

We develop a supply chain theory of factoring and reverse factoring showing when these post-shipment financing schemes should be adopted and who really benefits from the adoption. Given supplier's credit rating and trade credit term, recourse factoring is preferred when the supplier's cash investment return rate is relatively high; non-recourse factoring is preferred within certain medium range; otherwise, factoring should not be adopted. Further, we find that reverse factoring should only be offered to suppliers with medium cash investment return, and it is not always optimal for the retailer to extend the payment term in reverse factoring.

## ■ MB12

North Bldg 126A

**3D Printing**

Sponsored: Manufacturing &amp; Service Oper Mgmt

Sponsored Session

Chair: Michael R. Wagner, University of Washington, Seattle, WA, 98195, United States

Co-Chair: Mohammad Ebrahim Arbabian, University of Washington, Seattle, WA, 98105, United States

**1 - Managing Self-replicating Innovative Goods**

Bin Hu, University of North Carolina, Chapel Hill, NC, United States, Zhankun Sun

Inspired by self-replicating 3D printers, we investigate the business model for innovative goods whose demands follow Bass diffusion and whose production is through self-replication. Modeled as an optimal-control problem, we identify

clean structural properties of optimal production and sale policies and find them to be robust for a number of variations of the demand model. We also investigate uncertainty and learning of the diffusion parameter.

**2 - IP Licensing and 3D Printing of Spare Parts**

Bram Westerweel, Eindhoven University of Technology, Den Dolech 2, Eindhoven, 5600MB, Netherlands, Rob J. Basten, Jing-Sheng Jeannette Song

We consider an original equipment manufacturer (OEM) that supplies its customers with spare parts. In addition to a traditional channel for direct purchasing, the OEM can also offer customers the option of purchasing the spare parts design via a license agreement through which the customers can purchase spare parts from a local 3D printing service provider. We characterize the optimal contract structure to maximize the OEM's profit and we generate insights into the degree of decentralization of the supply chain when customers are offered a license agreement for local 3D printing.

**3 - The Impact of 3D Printing on Manufacturer Retailer Contractual Relationships**

Mohammad Ebrahim Arbabian, University of Washington, 5243 22nd Avenue NE, # 4, Seattle, WA, 98105, United States

As 3D printing is being recognized as a new technology in manufacturing, we study a wholesale-price contract where, on top of the traditional manufacturing, either the manufacturer or the retailer could adopt this new technology to produce final products. We analyze the equilibrium of the resulting games.

**4 - Moving to 3D Printing Technology for Spare Parts Supply**

Nils Knofius, University of Twente, Drienerlolaan 5, Building Ravelijn, Enschede, 7522NB, Netherlands, Matthieu van der Heijden, Henk Zijm

We analyze how and when a transition to 3D printing technology is advisable for spare parts supply during the remaining service horizon. Therefore, we consider an evolving inventory system where 3D printing production costs and demand rates may change over the course of the service horizon. Using a stochastic dynamic programming approach, we demonstrate that moving to 3D printing technology pays off under various conditions.

## ■ MB13

North Bldg 126B

**Emergency Department Operations**

Sponsored: Manufacturing &amp; Service Oper Mgmt/Healthcare Operations

Sponsored Session

Chair: Hummy Song, Philadelphia, PA, 19104, United States

**1 - Balancing Patient Care and Resident Supervision in Emergency Medicine: Resident Effect on Attending Physician Workload Study**

Yue Yin, Northwestern University, Evanston, IL, United States, Ernest Wang, Itai Gurvich, Jan A. Van Mieghem

We delineate the relationship between the presence of residents and the proportions of time spent on different tasks by emergency medicine attending physicians. We observed and compared how 25 emergency medicine attending physicians spent their time in an academic emergency department versus in a non-academic emergency department. We applied multivariate beta regression models to examine whether the overall presence of residence was associated with significant changes in physicians' time expenditures, controlling for physician workload, physician productivity, average patient acuity, waiting room crowdedness, and resident seniority.

**2 - An Econometric Analysis of How Facility Layout Impacts Care Provision in the Emergency Department**

Lesley Meng, The Wharton School, University of Pennsylvania, 3730 Walnut Street, Suite 500 JMH, Philadelphia, PA, 19104, United States, Robert Batt, Christian Terwiesch

We study how the facility layout of ED patient rooms impacts nurse workflow decisions. Specifically, linking our infrared nurse location tracking data to room occupancy patient data, we are able to investigate the impact of facility layout variables, such as distance from the nurses' station, on patient care quality in the ED.

**3 - Measuring Primary Care Performance Using ED Data**

Sandra S Iz, Erasmus University, Rotterdam, Netherlands, Nicos Savva

In the UK, access and clinical quality of GPs are difficult to measure either due to data unavailability, low frequency of data collection, or inconsistent data collection across GPs. ED-level data, however, exists and is comparable across hospitals. We therefore analyse whether ED-level data can be used to assess GP performance thereby distinguishing between accessibility for acute conditions and management of long-term care conditions.

**4 - Impact of Universal Healthcare on Patient Choice**

Diwas S. Kc, Emory University, 1300 Clifton Road, Goizueta Business School, Atlanta, GA, 30322, United States

This paper examines the role of universal healthcare on patient choice and quality of care. Lack of health insurance is a leading contributor to Emergency Department (ED) visits from the uninsured. We find that the availability of health insurance has a significant impact on the type of healthcare sought by the previously uninsured. Specifically, individuals are less likely to continue visiting the ED, and choose hospital inpatient and outpatient services instead. We also find an effect of the policy on quality of care, as measured by same-month patient revisits. Although overall revisit rates remain unchanged, frequent users experience a decline in same-month revisits.

**■ MB14**

North Bldg 126C

**Operations of Contemporary Services**

Sponsored: Manufacturing & Service Oper Mgmt/Service Operations

Sponsored Session

Chair: Opher Baron, University of Toronto, Toronto, ON, M5S 1L7, Canada

**1 - Matching Supply and Demand in a Service Network**

Levi DeValve, Duke University, 716 Turmeric Lane, Durham, NC, 27713, United States, Sasa Pekec, Yehua Wei

A service provider wishes to match stochastic supply and demand located on a network. With limited resources, the service provider can only choose a subset of nodes in the network where matches can be made, and wants to choose a subset maximizing its expected profit. Although this problem is NP-hard, we provide constant factor approximation guarantees for various heuristics, including a simple greedy policy. We also discuss several applications of this problem.

**2 - Spatial Pricing for Taxi Rides in New York City**

Nasser Barjesteh, Chicago, IL, 60615, United States, Baris Ata, Sunil Kumar

We conduct an empirical study of the impact of spatial prices on the performance of the taxi industry in New York City. We use a mean-field model, in which the taxi drivers strategically search for customers in different neighborhoods across the city taking into account the distribution of the supply and demand as well as the prices across the city. We conduct a series of counterfactual analyses to explore the impact of spatial prices on the distribution of supply and demand. We also investigate how spatial prices affect the welfare of customers and drivers and how the distribution of supply, demand, the destination of the rides, and the price sensitivity of the customers impact the optimal spatial prices.

**3 - Does the Bullwhip Matter Economically? A Cross-sectional Firm-level Analysis**

Jeffrey Callen, University of Toronto, Toronto, ON, Canada

We investigate whether the bullwhip effect measured at the firm level impacts firms' profitability. We estimate the relation between the bullwhip and various financial performance measures with a large panel of cross-sectional firm-level data. Performance is measured both in terms of mean effects and volatility effects. Our analysis yields results inconsistent with the notion that the bullwhip at the firm level has significant negative consequences on profitability. In particular, we find almost no significant statistical or economic negative relation between financial measures of profitability and the empirical bullwhip measures at the firm level, both with and without covariate controls.

**4 - Learning by Doing Versus Learning by Viewing: An Empirical Study of Data Analyst Productivity at Ebay on a Collaborative Platform**

Yue Yin, Northwestern University, Evanston, IL, United States, Itai Gurvich, Stephanie McReynolds, Debora Seys, Jan A. Van Mieghem

Effective data analytics drives business success by enhancing managerial decision-making. Companies, however, often struggle to maintain growth in the productivity of their data analysts. In this paper, we investigate how data-analyst productivity benefits from collaborative platforms that facilitate learning-by-doing (i.e. analysts learning by writing queries on their own) and learning-by-viewing (i.e. analysts learning by viewing queries written by peers). Productivity is measured using the time from creating an empty query to first executing it.

**■ MB15**

North Bldg 127A

**Joint Session MSOM/Practice Curated: Empirical Service Operations**

Sponsored: Manufacturing & Service Oper Mgmt/Service Operations

Sponsored Session

Chair: Vinayak Deshpande, The University of North Carolina at Chapel Hill

**1 - Improving Customer Compatibility with Operational Transparency**

MoonSoo Choi, Harvard Business School, 700 Soldiers Field Road, Wyss House, Boston, MA, 02163, United States, Ryan Buell

Recent research has demonstrated the impact of customer compatibility - the degree of fit between the needs of customers and the capabilities of the operations serving them - on service performance. Companies with more compatible customers receive higher satisfaction scores and exhibit faster growth. However, when marketing their offerings to prospective customers, companies often shroud the operational tradeoffs inherent in their offerings in favor of emphasizing their advantages. Through a large-scale field experiment with a nationwide retail bank, we investigate how providing prospective customers with transparency into an operation's tradeoffs affects acquisition and engagement.

**2 - Don't Call Us, We'll Call You: An Empirical Study of Caller Behavior under a Callback Option**

Brett Hathaway, The University of North Carolina at Chapel Hill, 1800 Baity Hill Drive #310, Chapel Hill, NC, 27514, United States,, Seyed Emadi, Vinayak Deshpande

Using call center data from a bank, we empirically study callers' decision-making process in the presence of a callback option. We formulate a structural model of their decision-making process, and impute their underlying preferences from the data. Our estimates of their preferences show that they experience almost no discomfort while waiting for a callback, and they incur a high cost of switching from their offline tasks to answer a callback. We conduct a counterfactual analysis of how various callback policies affect the service quality and system throughput of this call center. Our results indicate that offering callbacks increases service quality without substantially impacting throughput.

**3 - At Your Service on the Table: Impact of Tabletop Technology on Restaurant Performance**

Fangyun Tan, Southern Methodist University, 6212 Bishop Blvd, Dallas, TX, 75275, United States, Serguei Netessene

We use granular data to examine the impact of a tabletop device that facilitates the order process on the check size and meal duration aspects of restaurant performance. We find that the tabletop technology is likely to improve average sales per check by 2.91% and reduce the meal duration by 9.74%, which increases the sales per minute or sales productivity by approximately 10.77%. Overall, our results indicate great potential for introducing tabletop technology in a large service industry that currently lacks digitalization.

**4 - Decision Bias in the News Vendor Problem: Evidence from Airline Flight Scheduling**

Vinayak V. Deshpande, University of North Carolina at Chapel Hill, Kenan Flagler Business School, McColl Building, CB #3490, Chapel Hill, NC, 27514, United States, Milind Sohoni, Chandrasekhar Manchiraju

Research in Behavioral Operations Management has documented "Demand Chasing" and "Pull to Center" as two prevalent behavioral biases in the single period newsvendor problem in laboratory experimental settings. Using flight-scheduling data from the US Airline industry, we show that these biases exist even in real world managerial decisions. We also show that these biases exist not only at the individual level, but are also at the firm level.

## ■ MB16

North Bldg 127B

**Joint Session MSOM/Practice Curated: Renewable Energy Operations**

Sponsored: Manufacturing &amp; Service Oper Mgmt/Sustainable Operations

Sponsored Session

Chair: Nur Sunar, UNC, Chapel Hill, NC, 27517, United States

**1 - Pricing and Information in Short-term Sequential Power Markets with Renewable Energy**

Derck Koolen, Erasmus University-Rotterdam, Rotterdam, 3062PA, Netherlands, Derek W. Bunn

Motivated by the ongoing integration of renewable energy sources, we analyze sequential pricing in short-term power markets with a varying technology mix. We propose a multi-stage competitive equilibrium model to analyze retailers and heterogeneous producers' optimal sequential trading, allowing to capture the information transparency effect of large-scale and decentralized production on individual market participants' risk related hedging pressure. Empirical results, comparing the British and Californian market, validate the approach with respect to market specific exogenous operational constraints.

**2 - Smart Bike Lanes: A Data-driven Approach**

Sheng Liu, University of California, Berkeley, 1731 Spruce St Unit B, Berkeley, CA, 94709, United States, Zuo-Jun Max Shen, Xiang Ji

We develop a bike lane planning model based on the bike trajectory data. We formulate the bike lane planning problem as an integer program to maximize the coverage of cyclists as well as the continuity of bike lanes. We develop a Lagrangian relaxation method to solve the model efficiently by exploiting its structure. We apply the model to Zhuhai city of China using the real trajectory data from a dock-less bike sharing system. The construction plan of our model can benefit tens of thousands of cyclists in Zhuhai and promote cycling as a healthy and sustainable transit mode. We collaborate with the urban planning institution of Zhuhai to implement the model.

**3 - Capacity Investment in Wind Farms: The Role of Subsidy Policies**

Foad Iravani, University of Washington, Foster School of Business, ISOM Department, Box 353226, Seattle, WA, 98195-3226, United States, Saed Alizamir, Safak Yucel

The U.S. government offers output-based and cost-based subsidies to promote investment in wind farms. We analyze the decision of wind farms to choose one of the two subsidies and study the effect of subsidies on the farms' capacity decisions.

**4 - Meeting Corporate Renewable Energy Targets**

Selvaprabu Nadarajah, College of Business, University of Illinois at Chicago, 601 South Morgan Street., UH 2406, Chicago, IL, 60607, United States, Danial Mohseni-Taheri, Alessio Trivella

Several companies have committed to procuring a percentage of their power demand from renewable sources by a future date. We study the dynamic procurement problem to meet this target by purchasing power via virtual power purchase agreements (PPA) and the wholesale spot market, which are two dominant strategies. We analyze the change in procurement cost under different target levels and PPA strike price structures used in practice, as well as, characterize substitution between the strike price and the target level. To assist in computing multi-stage procurement portfolios, we develop a dual reoptimization based approximate dynamic programming policy and present results on realistic instances.

**5 - Implications of Independent Renewable Power Producers for Utility Companies**

Nur Sunar, UNC, 1604 Village Crossing Drive, Chapel Hill, NC, 27517, United States, Jayashankar M. Swaminathan

It is widely believed that the existence of independent renewable power producers hurts the profitability of utility companies. We identify a prevalent practical setting in which the existence of independent renewable energy producers increases the profitability of utilities. We complement our results with data analysis.

## ■ MB17

North Bldg 127C

**SCM SIG Special Session: Emerging Topics in Supply Chain Management**

Sponsored: Manufacturing &amp; Service Oper Mgmt/Supply Chain Sponsored Session

Chair: Lauren Xiaoyuan Lu, University of North Carolina at Chapel Hill, Kenan Flagler, Chapel Hill, NC, 27599, United States

Co-Chair: Guoming Lai, Austin, TX, 78712, United States

**1 - Industry 4.0**

Brian Tomlin, Tuck School of Business, Dartmouth College, 100 Tuck Hall, Hanover, NH, 03755-9000, United States

In this talk I will discuss Industry 4.0 (sometimes referred to as the 4th industrial revolution) and briefly highlight research opportunities and challenges relevant to the operations management community.

**2 - Responsible Operations: Challenges and Opportunities**

Jayashankar M. Swaminathan, University of North Carolina Chapel Hill, Kenan-Flagler Business School, Operations, Chapel Hill, NC, 27599-3490, United States

In this talk I will discuss about the key opportunities for OM researchers in the area of responsible operations. I will also discuss some of the challenges associated with doing such research.

**3 - Agriculture 4.0**

Tava Olsen, University of Auckland, ISOM, Business School, University of Auckland, Auckland, 1142, New Zealand

Agriculture is changing in many ways. This talk gives an overview of these changes, with a particular focus on agricultural supply chains. In particular, we discuss agricultural cooperatives and how they shift the power in the supply chain. We will also discuss new agricultural technologies and precision agriculture.

## ■ MB18

North Bldg 128A

**Joint Session JPS/Practice: Industry Job Search Panel**

Emerging Topic: INFORMS Career Center

Emerging Topic Session

Chair: Warren Hearn, Cardlytics, 4061 Water Oak Terrace SW, Lilburn, GA, 30047-7417, United States

**1 - Industry Job Search Panel**

Warren Hearn, Cardlytics, 4061 Water Oak Terrace SW, Lilburn, GA, 30047-7417, United States

This panel discusses the industry interview process and do's and don'ts associated with the job search. In addition to comment from current and former recruiters, time will be provided for questions and answers.

## ■ MB19

North Bldg 128B

**New Models for Assortment Planning and Pricing**

Sponsored: Revenue Management &amp; Pricing

Sponsored Session

Chair: Sumit Kunnumkal, Queen's University, Smith School of Business, Kingston, ON, Canada

**1 - Assortment Optimization for a Multi-stage Choice Model**

Zizhuo Wang, University of Minnesota, 1009 5th Street SE, Minneapolis, MN, 55414, United States, Yunzong Xu

Motivated by a practical selling scenario that requires previous purchases to unlock future options, we consider a multi-stage assortment optimization problem, where the seller makes sequential assortment decisions with commitment, and the customer makes sequential choices to maximize her expected utility. We show that this problem is polynomial-time solvable when the customer is fully myopic or fully forward-looking. The optimal policy entails that the assortment in each stage is revenue ordered and a product with higher revenue always lead to a wider range of future choices. We also show that the problem is NP-hard in general and give precise/approximation algorithms for various scenarios.



**2 - Price Optimization under an N-pack Choice Model**

Guang Li, Queen's University, Smith School of Business,  
Kingston, ON, Canada, Ying Cao

We consider the price optimization problem for a retailer under an n-pack choice model. Under such a model, each customer would either purchase n items from a collection of m products or leave with no purchase. Given an offered assortment, the retailer aims at maximizing his total revenue by setting the right price for each product. We study the structural properties of the optimal prices under different pricing schemes and develop efficient algorithms for price optimization

**3 - Operations Management under Sequential Choice Models**

Ruxian Wang, Johns Hopkins University, Carey Business School,  
100 International Dr, Baltimore, MD, 21202, United States

Consumers may follow a sequence to choose the products they would like to choose. We study the operations management problems and derive useful managerial insights.

**4 - Assortment Planning with N-pack Purchasing Consumers**

Ying Cao, University of Texas at Dallas, Dallas, TX, United States,  
Dorothee Honhon

For many product categories, customers often buy multiple differentiated products on a given store visit for staggered consumption until the next store visit. Such customers are referred to as n-pack purchasing customers in Fox et al (2017). We consider a retailer who makes product assortment decisions in a given product category facing n-pack purchasing customers. We study the structural properties of the optimal assortment under two different customer choice rules. And we explore how the retailer's assortment decision and total profits are impacted when the retailer ignores the "choice premium which captures the utility that consumers derive from variety in their shopping basket.

**■ MB20**

North Bldg 129A

**Joint Session RMP/Practice Curated: Sharing Economics**

Sponsored: Revenue Management & Pricing

Sponsored Session

Chair: Han Zhu

**1 - Courteous or Crude? Operational Tools to Shape User Behavior in Ride-sharing Platform with Bilateral Ratings**

Yunke Mai, Duke University, Durham, NC, United States,  
Yuhao Hu, Zilong Zou, Bin Hu, Sasa Pekec

We study the impact of riders' manners and drivers' selectiveness on the performance of ride-sharing platforms. We develop an evolutionary game-theory model to study how user behavior on the platform evolve over time under a bilateral rating system. We identify evolutionary trajectories of user behavior and stable equilibria for the platform usage as a function of the system parameters. In addition, we investigate how platform's operational decisions such as pricing, supply/demand management, and choice of matching protocols impact user behavior and platform's long-run performance.

**2 - Analysis of Incentivized Ride Matching as Stackelberg Queue**

Shumin Ma, The Chinese University of Hong Kong, ERB615,  
CUHK, Hong Kong, Qi Wu

We study incentive strategies using a queueing game approach. Our key assumption is that the driver supply is finite and reusable while riders arrive stochastically. With this assumption, we first establish the endogenous forces driving the imbalances between supply and demand with zero monetary incentive. We then administer incentives between the platform and the driver population via Stackelberg games and study the system's intrinsic capacity bounds in steady state. We show that the optimal amount of myopic incentives is achieved when the circulation of the reusable pool of the driver supply is the fastest. Further spending beyond the optimal, however, is potentially disruptive.

**3 - Dynamic Type Matching**

Yun Zhou, McMaster University, 1280 Main Street West,  
Hamilton, ON, L8S 4M4, Canada, Ming Hu

Motivated by the sharing economy, we consider a dynamic matching problem with heterogeneous supply and demand types. This paper studies the optimality and near-optimality of matching policies under a given priority rule. For two cases with vertical and horizontal types, respectively, we characterize the optimal prioritized matching policy.

**4 - Short-term Asset Rentals and Corporatization of Platform Pricing**

Han Zhu, McGill University, Montreal, QC, H3H 1K4, Canada,  
Mehmet Gumus, Saibal Ray

Recently, we have seen the emergence of short-term rentals platforms. In this paper, we focus on how the platform decides on the price to charge their customers. Specifically, in a platform like Airbnb, the price is effectively set based on a market mechanism that matches supply and demand. But, some other platforms are more active. They take turnkey control of the assets and determine the price on behalf of the owners that maximizes their profits. Our primary goal in this paper is to understand the implications of this difference in pricing strategy for the direct stakeholders of the platform such as customers, owners and the platform as well as indirect stakeholders such as long-term rentals and hotels.

**■ MB21**

North Bldg 129B

**Advances in Demand Learning for Revenue Management**

Sponsored: Revenue Management & Pricing

Sponsored Session

Chair: Pavithra Harsha, IBM Research, Yorktown Heights, NY, 10598, United States

**1 - Choice Model Trees: A Joint Framework for Market Segmentation and Decision Making**

Ryan McNellis, Columbia University, 540 West 122nd Street,  
Apartment 6C, New York, NY, 10027, United States,  
Mohammed Ali Aouad, Prasad Chalasani, Adam Elmachtoub,  
Kris Johnson Ferreira, Michael R. Young

We propose a new method for incorporating feature information into marketing decision-making problems. Relevant applications include the recommendation of personalized product assortments, personalized pricing, and customizing bids for advertising exchanges. Our method uses a decision tree to segment the market (e.g., customers), and a choice model involving the decision variable (e.g., product assortment) is then fit locally in each segment. The resulting model is interpretable and easily visualized. We propose a new training algorithm which directly optimizes the likelihood of the resulting collection of choice models. Modifications are explored for improved scalability.

**2 - A Model-based Embedding Technique for Segmenting Customers**

Ashwin Venkataraman, Harvard University, Cambridge, MA,  
United States, Srikanth Jagabathula,  
Lakshminarayanan Subramanian

We consider the problem of segmenting a large population of customers into non-overlapping groups with similar preferences, using diverse signals such as purchases, ratings, clicks, etc. over a large universe of items, when each customer provides only a few signals. We propose a model-based embedding technique which takes the customer observations and a probabilistic model class generating the observations as inputs, and outputs an embedding—a low-dimensional representation in Euclidean space—for each customer. We then cluster the embeddings to obtain the segments. We demonstrate the speed and performance of our method in two case studies including a real implementation on eBay data.

**3 - Dynamic Pricing of Limited Inventories with Product Returns**

Xing Hu, University of Oregon, 1208 University Of Oregon, 484  
Lillis, Eugene, OR, 97403, United States, Zhixi Wan,  
Nagesh N. Murthy

Many online retail channels face high rates of product returns. This poses a new challenge to the sellers' dynamic pricing problem when some returns in good condition can be resold in the selling season. To study the impact of product returns and guide sellers to adjust pricing policies, we build a product returns model by augmenting the classic monopolist's dynamic pricing framework. We address the technical challenges both analytically and numerically. Our analysis finds that ignoring returns leads to over-pricing and can cause significant revenue loss. The analysis yields easy-to-implement heuristic policies that have good and robust performance relative to the theoretical benchmarks.

## ■ MB22

North Bldg 130

**Topics in Market Design and Multi-agent Systems**

Sponsored: Revenue Management &amp; Pricing

Sponsored Session

Chair: Itai Ashlagi, Stanford University, Stanford, CA, 94305, United States

**1 - Information and Pricing Mechanisms for On-demand Platforms**

Guido Martirena

I consider the design of information and pricing mechanisms in an unobservable queue with strategic and heterogeneous customers that are privately informed. I show that 1) if the platform releases all the information, then among all possible pricing mechanisms the platform wishes to set a sequence of posted prices, 2) for any information policy, the steady-state can be replicated by full-information and prices while achieving a higher revenue, 3) optimizing among all possible pricing and information mechanisms, the optimum is to disclose all the information and set a sequence of posted prices, and 4) I identify conditions under which the platform profits from releasing information strategically.

**2 - Exploration vs. Exploitation in Team Formation for Collaborative Work**

Hannah Li, Stanford University, Palo Alto, CA, 94306, United States, Ramesh Johari, Vijay Kamble, Anilesh Krishnaswamy

Service platforms face an online learning problem in matching workers with jobs and using the performance on these jobs to create better future matches, a problem complicated by the presence of complex tasks that require a team of workers to complete. The success of a complex job depends on the skills of all workers, which may be unknown to the platform. We analyze two settings where the performance of a team is dictated by its strongest and weakest member, respectively, and find that both problems pose an exploration-exploitation tradeoff. We establish regret bounds and show how certain myopic strategies are optimal depending on the setting as well as the proportion of high quality to low quality workers.

**3 - Maximum Weight Online Matching with Deadlines**

Maximilien Burg, PhD Student, Massachusetts Institute of Technology, 77 Massachusetts Avenue, Cambridge, MA, 02139, United States, Itai Ashlagi, Amin Saberi

We study the finite horizon problem of matching agents who arrive at a marketplace over time and leave after  $d$  time periods. Each pair of agents can yield a different match value, and we study matching algorithms that perform well over adversarial graphs, when the arrival order of agents is random.

We show that the widely used “batching” algorithm, which periodically computes a maximum-weight matching, is 0.279-competitive when the period is  $d$ . Our analysis relies on a reduction to a graph-theoretic covering problem. We show that the competitive ratio is the limit solution of a family of linear programs, and we provide a computer aided bound on this limit.

**4 - Markets for Public Decision-making**

Nikhil Garg, Stanford University, Ashish Goel, Ben Plaut

A public decision-making problem consists of a set of issues, each with multiple possible alternatives, and a set of competing agents, each with a preferred alternative for each issue. We study adaptations of market economies to this setting. We first show that when each issue has a single price that is common to all agents, market equilibria can be arbitrarily bad. We then transform the problem into an equivalent Fisher market, the simplest type of private goods market. We show that the equilibrium prices in the constructed Fisher market yield a pairwise pricing equilibrium in the original public decision-making problem which maximizes Nash welfare.

## ■ MB23

North Bldg 131A

**Modern Trends in FinTech and Financial Networks**

Sponsored: Finance

Sponsored Session

Chair: Agostino Capponi, Columbia University, New York, NY, 10027, United States

**1 - R&D in Bitcoin Mining**

Humoud Waleed Alsabab, Columbia University, New York, NY, United States

We study a two-stage game where firms first invest in research and development (R&D) to subsequently compete in a Bitcoin mining game at reduced costs. We show that whether or not a firm is active in a mining game depends on the firm's hash rate costs and not on the rewards that can be obtained from mining. Increasing rewards, on the other hand, induce firms to exert higher hash rates and R&D efforts. We show that while an increase in R&D spillover reduces the

firm's R&D investment, it may still trigger the exertion of a higher total hash rate.

**2 - Propagation of Credit Freezes in Financial Lending Networks**

James Siderius, Massachusetts Institute of Technology, Boston, MA, United States

We consider a network model of financial intermediation where banks decide whether to extend credit to other banks, which may then default on those loans. In contrast to previous literature on financial networks, the focus is on how “fear of future default” can lead to “credit freezes” before the realization of these uncertainties. Specifically, we show that increases in the riskiness of one or a few banks can lead to systemic credit freeze throughout the financial network. This occurs because the consequences from uncertainty travel throughout the network as well as decrease the profitability of loans. We use this framework to analyze the effects of policy interventions on systemic credit freezes.

**3 - DGM: A Deep Learning Algorithm for Solving Partial Differential Equations**

Konstantinos Spiliopoulos, Boston University, 111 Cummington Mall, Boston, MA, 02215, United States

We propose to solve high-dimensional PDEs by approximating the solution with a deep neural network which is trained to satisfy the differential operator, initial condition, and boundary conditions. We prove that the neural network converges to the solution of the partial differential equation as the number of hidden units increases. Our algorithm is meshfree, which is key since meshes become infeasible in higher dimensions. We implement the approach for American options in up to 200 dimensions. We call the algorithm a “Deep Galerkin Method (DGM)” since it is similar in spirit to Galerkin methods, with the solution approximated by a neural network instead of a linear combination of basis functions.

**4 - Welfare Analysis of Central Bank Digital Currency: Privacy versus Efficiency**

Christoph Frei, University of Alberta, Mathematical and Statistical Sciences, CAB 621, Edmonton, AB, T6G 2G1, Canada, Agostino Capponi

A Central Bank Digital Currency (CBDC) is electronically transacted and stored money, similar to existing cryptocurrencies like Bitcoin, but guaranteed by a central bank. If a central bank introduced a CBDC, it could provide the public with a cheaper payment system, leading to efficiency gains compared to a traditional currency. However, a CBDC may compromise users' privacy because transactions could be monitored by the state's authority. In this talk, we present a model featuring the trade-off between efficiency and privacy faced by people who decide between different payment methods, and analyze the welfare implications of a CBDC.

## ■ MB24

North Bldg 131B

**Emerging Business Models in Information Systems**

Sponsored: EBusiness

Sponsored Session

Chair: Manmohan Aseri, The University of Texas at Dallas, Richardson, TX

**1 - Are You Paying Too Much for Financial Advice? Measuring the Value of Information on a Social Trading Platform**

Mingwen Yang, The University of Texas at Dallas, JSOM, UTD, 800 W. Campbell, SM 33, Richardson, TX, United States, Vijay S. Mookerjee, Zhiqiang Eric Zheng

This study investigates the information value on a social trading platform. The platform releases the on-going transactions adding some time delays for public. Investors face the tradeoff between receiving real-time trading information paying higher commission and receiving delayed information with lower commission. Using individual trading data from a social trading platform and Forex spot price data, we simulate the profits with some time delays and measure the information value of following a trader in real time. We investigate how different factors (e.g., open time delay, close time delay, amount following by investors, market volatility, etc.) influence the information value.

**2 - Selecting a Portfolio of Mobile Ad Exchanges**

Leila Hosseini, The University of Texas at Dallas, Richardson, TX, Vijay Mookerjee

The trend of the last several years has been that people spend most of their mobile time in Apps. Following this trend, mobile advertisers and publishers have been focusing on running advertising campaigns inside mobile Apps to maximize their revenue. Mobile Ad delivery platforms participate in some auctions to buy supply from mobile Ad exchanges who help App owners to sell their Ad places. In this study, we analyze a planning model for a platform which needs to cover advertisers' demand by procuring supplies from multiple Ad exchanges. The planning problem amounts to selecting which of the given set of Ad exchanges to retain, so as to minimize total costs while ensuring that the advertisers' demand is met.

**3 - Bitcoin and Its Cost**

Sailendra Mishra, The University of Texas at DallasRichardson, TX

As cryptocurrencies are bid to become more mainstream, we investigate resources needed to operationalize these at large scale. Our research highlights how Bitcoin's complexity, transaction volume, and exchange rate affect computing power required in validating transactions in Bitcoin. Our findings suggest that Bitcoin's protocol induces competition and computational power race, which may deterrence to the future growth of the system.

**4 - How to Sell a Dataset? Pricing Policies for Data Monetization**

Sameer Mehta, The University of Texas at Dallas, 800 W. Campbell Rd, SM 33, Richardson, TX, 75080, United States,

Milind Dawande, Ganesh Janakiraman, Vijay Mookerjee

The wide variety of pricing policies used in practice by data-sellers suggests that, as yet, there is no common understanding on how data should be priced. The selling of data - arranged in a row-column format, where rows represent records and columns represent attributes of the records - is significantly different from that of information goods like telephone minutes and bandwidth, in the sense that, for a buyer, it is not just the amount of data (i.e., the number of records) that matters but also the "type of the data. In this study, we develop a utility framework that is appropriate for data-buyers and address the corresponding pricing of the data by a seller.

**■ MB25**

North Bldg 131C

**Joint Session Service Science/Practice Curated: NSF Funding Opportunities for Service Science Researchers**

Sponsored: Service Science

Sponsored Session

Chair: Alexandra Medina-Borja, PhD, National Science Foundation, Alexandria, VA, 22314, United States

**1 - NSF Funding Opportunities for Service Science Researchers**

Alexandra Medina-Borja, PhD, National Science Foundation, Alexandria, VA, 22314, United States

Technologies are enabling an era of smart everything while service systems continue to dominate industrialized economies. As the concepts of smartness and service are starting to fuse, modeling of smart engineered systems is becoming challenging. While applying a "service framework to this partnership of humans and machines could help, society is still concerned with machines replacing workers in the service sector. Myriad convergent research opportunities in this new landscape are possible. NSF Program Officers will discuss some funding opportunities at the National Science Foundation, both in terms of the NSF's Ten Big Ideas for Future Investment and research funding for re-skilling the service workforce.

**■ MB26**

North Bldg 132A

**Emerging Topics in Service Operations 2**

Sponsored: Service Science

Sponsored Session

Chair: Yuqian Xu, University of Illinois at Urbana-Champaign, Champaign, IL, 61820, United States

**1 - Jobenomics - Text Data Analytics on Job Posting**

Jing Wu, City University of Hong Kong, Department of Management Sciences, Rm 7-233, Lau Ming Wai Academic Building, Hong Kong, Hong Kong

We use natural language processing tools on >50-million job postings representing >30,000 private and public companies as well as >20-billion words captured in the position descriptions to explain firm performance and human capital investment. Our preliminary results show that job posting information has strong predictive power on firm productivity growth and stands out uniquely compared to common asset pricing factors.

**2 - Dynamic Pricing of the Ride Sharing Market in a Spatial Search Model**

Weiming Zhu, IESE Business School, Avenida Pearson 21, Barcelona, 08034, Spain, Liu Ming, Jingting Fan, Wenlan Luo

Ride-sharing platforms employ flexible pricing during peak hours to match supply with demand. In this study, we build a spatial search model to study the geographic dynamics among drivers. Utilizing data from a leading ride-sharing platform, we assess the impact of different pricing schemes on drivers' capacity distribution, platform profit, and consumer surplus.

**3 - Coping with the Bullwhip Effect through Inventory or Cash: An Environment-behavior-performance Paradigm**

Baile Lu, Zhejiang University, Hangzhou, China, Weihua Zhou, Baofeng Huo, Qihui Gong

An environment-behavior-performance paradigm was proposed to examine the impact of the bullwhip effect on coping behavior and performance, where the bullwhip effect is regarded as an environmental factor, inventory and cash holdings are regarded as factors for coping with the bullwhip effect, and risk is defined as company performance. Our analysis shows that the bullwhip effect is positively related to both operating and equity risks, and is positively related to inventory and cash holdings. A moderate level of inventory is negatively related to operating and equity risks, and cash is only negatively related to operating risk; however, excess resource holdings are positively related to risk.

**4 - Is on Demand Car Rental a Complement or Substitute for Private Car and Public Transit?**

Lixian Qian, Xi'an Jiaotong-Liverpool University, IBSS Building, South Campus, Xi'an Jiaotong-Liverpool University, Suzhou, 215123, China, Zhan Pang, Didier Soopramanien

On-demand car rental has emerged as a prominent alternative mobility mode to private car usage in urban areas. However, it remains unclear whether it is a complement or substitute for private car and public transit. To find the empirical evidence, we conducted a choice-based conjoint study in Beijing. We find that service accessibility and mobility speed, as well as consumer car ownership and purchase intention, are key drivers of mobility choice. Although on-demand car rental may reduce private car usage, it may also attract public transit users, resulting in an unanticipated rise in total car usage.

**■ MB27**

North Bldg 132B

**Developing Robust Analytics Curricula**

Sponsored: Education (INFORMED)

Sponsored Session

Chair: Carrie Beam, University of Arkansas, Fayetteville, AR, 94596, United States

**1 - What We Hire: Analytics Skills We Want Schools to Teach our Job Applicants**

Aaron Burciaga, VP Data Science and Machine Intelligence at Booz Allen Hamilton,

Will give a spirited overview of analytics skills and that are critical to hire, and others that differentiate, in today's workplace. Aaron will provide useful insights towards attaining and balancing the right mix of education, experience, and elocution needed for a successful and enduring career and legacy.

**2 - Arkansas Robust Analytics Curricula**

Carrie Beam, University of Arkansas, Walnut Creek, CA, 94596, United States

How can you teach R programming, online, to students who have never written code before? Is it possible to get them running K-Means, linear regression, and rpart trees without breaking the Internet? In this session, I'll show you the mechanics of how we implemented an Introduction to Analytics class online at the University of Arkansas.

**3 - Designing and Deploying a Profession-centered Business Analytics Program**

Sanjay Saigal, University of California-Davis, Davis, CA, United States

As the "sexiest profession of the 21st century" gains prominence, colleges have responded: ~40 new programs start up in Analytics & Data Sc every year. How do we create a program that balances department strengths with employer needs and student profiles? UC Davis offers three established MBA programs and a newer master's in Accountancy. Our "all new" MS in Business Analytics aims for industry relevance, practicality, and student ROI. We evaluate our MSBA design elements and their deployment in the 2017-18 school year, our first. We focus on the highly intensive year-long Industry Practicum and related courses covering one quarter of the total credits.

**4 - Analytics for Undergrads: How It's Done at a Small Liberal Arts College**

Anthony Bonifonte, Denison University, 3267 Raccoon Valley Rd, Granville, OH, 30106, United States

Denison University's Data Analytics program was founded in 2016 and has already attracted considerable student interest. As a small, undergraduate only liberal arts institution, the program is highly interdisciplinary and focuses on equipping students with the knowledge and skills to solve practical data problems and training them to effectively communicate results. Each core course is project-driven, and students complete a semester-long mock consulting experience with on-campus clients. Student also choose 7 concentrations in natural and social science disciplines. In this talk I will share the curriculum and philosophy behind its' design and some initial student outcomes.



**5 - Results from an Analytics Benchmarking Study**

Andrew Urbaczewski, University of Denver, Daniels College of Business 593, 2101 S. University Boulevard, Denver, CO, 80208, United States

I will present the results from my Analytics Benchmarking Study. I have looked at dozens of Business Analytics/Data Analytics/Analytics/Data Science/etc. Programs and compared tuition, pre requisites, credit hours, and expected length to complete.

**■ MB28**

North Bldg 221A

**Yard and Terminal Operations**

Sponsored: Railway Applications

Sponsored Session

Chair: Tyler Dick, U. of Illinois at Urbana-Champaign, Urbana, IL, 61801, United States

**1 - The Digital Transformation of Rail Yard Planning and Operations**

Jeremiah Dirnberger, GE Transportation, 7572 Old Kings Rd S, Jacksonville, FL, 32217, United States

Rail yards are vital to overall network fluidity but have had limited technological investment relevant to other areas. GE Transportation is advancing a holistic solution to enhance reliability, reduce maintenance overhead, improve utilization of existing capacity, and increase margins and volume through these critical nodes. Information is analyzed at the edge and passed on for use by an integrated suite of inventory management and decision support tools. The work impact at downstream yards on and off each network are considered and decisions automatically made to improve productivity, reliability and flexibility, while enabling safer operations through effective use of automation.

**2 - Improving the Flat Switching Process**

Roger Baugher, TrAnalytics, Johns creek, GA, United States, Daril Vilhena

One of the most daunting challenges in many yards and terminals is developing and implementing efficient switching sequences - the process of taking cars from multiple tracks and building blocks most expeditiously while ensuring train makeup rules are enforced. The challenge is especially daunting in medium-sized to large flat yards. Railroads have spent heavily to implement yard management systems, but these systems typically provide little guidance on how to switch the cars. Excellent yardmasters can perform this mathematically-challenging task well, but their population is dwindling as experienced railroaders retire. The author will discuss the development of a set of new tools that provides new capabilities and improves yard performance in both time and cost.

**3 - Traffic Complexity and the Performance of Railway Classification Yards**

Tyler Dick, U. of Illinois at Urbana-Champaign, 1241 Newmark Lab MC-250, 205 N. Mathews Avenue, Urbana, IL, 61801, United States

In designing a train plan for a railway network, one decision is to determine the number of blocks to be handled by each train and the number of blocks to be assembled at each classification yard while maintaining a certain level of service. This research uses Optym YardSYM to investigate the relationship between throughput volume, the total number of blocks assembled and the level of service at a hump classification yard. To supplement this initial analysis, the research also investigates the influence of number of departing trains, block size distribution and schedule and volume variability on yard performance.

**4 - Car-Scheduling Based Hump Sequencing**

Roger Baugher, TrAnalytics LLC, Johns Creek, GA, United States, Chip Kraft

In a car-scheduling driven approach to hump sequencing, the goal is not to make all connections, but to ensure that at least the most important ones are protected. Yard management uses the tool to decide whether to hold outbound train departures for a short time, or else drop the connection if the delay would be too long.

**■ MB29**

North Bldg 221B

**Information and Preferences in Traffic Flows**

Sponsored: TSL/Urban Transportation

Sponsored Session

Chair: Laiyun Wu, SUNY-Buffalo, 326 Bell Hall, Buffalo, NY, 14226, United States

**1 - Modeling Spatiotemporal Information Flow Propagation in a Vehicle-to-vehicle- Communication System Considering Communication Delays**

Yangjiao Chen, Purdue University, West Lafayette, IN, United States

This study develops an analytical Markov model to characterize the spatiotemporal propagation of information under vehicle-to-vehicle (V2V) communications while factoring traffic dynamics and communication delays due to communication failure and communication frequency. A closed-form solution of the expected information propagation speed is derived under different densities of equipped vehicles. Numerical experiments demonstrate the effectiveness of the proposed model in various traffic conditions.

**2 - Evaluating the Cognitive Effects of Real-time Travel Information using Psychophysiological Analysis and their Implications for Driver Decision-making**

Shubham Agrawal, Purdue University, West Lafayette, IN, 47906, United States

This study conducts interactive driving simulator-based experiments to evaluate the impacts of driver cognitive state (for example, mental workload and engagement level) on the driver route choice decision-making process under real-time travel information provision. The driver cognitive state is estimated by analyzing the physiological data collected using electroencephalogram (EEG), electrocardiogram (ECG) and wearable eye-tracking glasses. The systematic differences in driver cognitive state are analyzed based on the characteristics of the disseminated real-time information and heterogeneity in individual characteristics.

**3 - Expectations of the Driver's Role when Using an Automated Driving System**

Dustin Souders, Purdue University, West Lafayette, IN, United States

This study investigates the effects of introductory materials on participants' interaction with an automated driving system (ADS; SAE level 3) in a simulated environment. Young and old participants are engaged in a secondary task while monitoring an ADS, and vigilance patterns (eye-tracking, EEG), take-over performance, trust and acceptance attitudes will be assessed. Results will inform how licensing agencies and OEMs should train drivers when using level 3 automation during this transitional period in road vehicle automation to ensure proper expectations and encourage safety.

**4 - Cooperative Adaptive Cruise Control for Connected Autonomous Vehicles by Factoring Communication-Related Constraints**

Chaojie Wang, Purdue University, West Lafayette, IN, United States

We propose cooperative adaptive cruise control (CACC) strategies for connected autonomous vehicles (CAVs) to enhance platoon performance by temporarily switching off the V2V communication functionality for some CAVs in the platoon. An optimization model is established to determine the optimal information flow topology that can maximize platoon performance based on one or more objectives (string stability, smoothness and convergence rate of the platoon control strategy) under the communication-related constraints. The effectiveness and efficiency of the proposed CACC strategies for CAV platoons will be illustrated using numerical simulation.

**5 - Inferring Origin-Destination and User Preference in Multi-modal Travel Environment by Using Automated Fare Collection Data**

Laiyun Wu, SUNY-Buffalo, 326 Bell Hall, Buffalo, NY, 14226, United States

The Origin-Destination (OD) demand data availability and quality are critical for the effective and efficient operation and management of a transit system. Understanding of transit user preferences, at the same time, is also important for planning and assessing transit systems. In this paper, we develop and apply an inference framework for distilling multi-modal routing preferences for transit system users and their true OD through a probabilistic learning method, based on a real-world Automated Fare Collection data set.

## ■ MB30

North Bldg 221C

### Joint Session TSL-FAC/SOLA: Strategic Location/Allocation of Resources

Sponsored: TSL/Facility Logistics

Sponsored Session

Chair: Felipe Aros-Vera, Ohio University, Athens, OH, 45701, United States

#### 1 - Optimal Districting of Disaster Areas

Johanna Amaya Leal, Iowa State University, Ames, IA, United States, Jose Holguin-Veras, John E. Mitchell

This paper describes a methodology to solve the problem of districting a disaster area among relief groups in post-disaster situations. Building upon formulations that minimize the total social costs of the operation, a districting strategy is proposed to expedite the flow of critical supplies to demand points. The model considers the resources the relief groups, capacity of sites, and the needs of the population to minimize the human impacts of the disaster

#### 2 - The Integration of Research and Development, Manufacturing and Distribution in Humanitarian Supply Chains

Nico Vandaele, KU Leuven, Naamsestraat 69, 0419.052.173, Leuven, 3000, Belgium, Catherine Jenny Decouttere, Kim De Boeck, Stef Lemmens, Mauro Bernuzzi

Based on both our academic as well as our field work we elaborate on the importance of interconnecting R&D, manufacturing and distribution activities in vaccine supply chains. The ultimate goal of immunization and being prepared for outbreaks is highly dependent on a number of design and managerial decisions taken decades before the operations materialize and when responsiveness becomes key. We illustrate this with evidence from our modelling work in vaccine manufacturing as well as in local distribution settings in some sub-Saharan countries.

#### 3 - A Framework to Assess Location of Micro Grids to Increase Energy Grid Resilience

Felipe Aros-Vera, Ohio University, 277 Stocker Center, 1 Ohio University, Athens, OH, 45701, United States, Shayne Gillian, Austin Rehmar, Landon Rehmar

This paper develops a framework to assess the location of microgrids to increase resilience of an electrical power system and mitigate the impact of catastrophic grid failure in disaster situations. Using optimization models and network vulnerability analysis, the framework determines where to locate a set number of microgrids to provide maximum benefit to a population. This paper uses a case study of the 2017 hurricane season that caused catastrophic grid failure on the island of Puerto Rico to evaluate the allocation of microgrids on critical infrastructure.

#### 4 - A Stochastic Model to Allocate Water in Post-disaster Environments

Diana Ramirez-Rios, Rensselaer Polytechnic Institute, 134 25th Street, Troy, NY, 12180, United States, Sofia Perez-Guzman, Trilce Encarnacion, John E. Mitchell, Jose Holguin-Veras

This study develops a stochastic mixed integer programming formulation for the allocation of water when there exists an uncertainty of time the population will return to normalcy. In the case of water deprivation, this commodity is usually expected during the first days after the disaster occurs, and it is known that if a person lacks water, after 5 days they will die. This formulation considered five scenarios related to the days expected for return to normalcy. Results from a case study provide an idea of the magnitude of human suffering in distribution of aid during post-disaster response.

## ■ MB31

North Bldg 222A

### New Data, Models, and Technology for Public Transportation

Sponsored: TSL/Intelligent Transportation Systems (ITS)

Sponsored Session

Chair: Stefan Voss, University of Hamburg, Institute of Information Systems (IWI), Von-Melle-Park 5, Hamburg, 20146, Germany

#### 1 - A Stochastic User Equilibrium Model for Integrated Transit and Ride-Sourcing Services

Yufeng Zhang, University of Minnesota, 500 Pillsbury Drive S.E., Room 175, Minneapolis, MN, 55455, United States, Alireza Khani

Integrating transit and ride-sourcing services can improve mobility by providing solutions for the "first/last mile problem. This study explores the equilibrium between the demand for the integrated system and the ride-sourcing drivers'

participation (supply), where interactions exist in that a service quality improvement of the integrated transit-ride-sourcing will attract more users for the combined mode and thus create incentives for more driver participation. An elastic demand stochastic user equilibrium model is developed and shows overall service improvement.

#### 2 - Integrating Ride-shared Mobility-on-Demand (MOD) System with Public Transit

Liu Xu, PhD Candidate, University of Maryland-College Park, 1173 Glenn L. Martin Hall,, College Park, MD, 20742, United States, Xinlei Zhang, Ali Haghani

Seamless integration of ride-shared MOD service with public transit may offer sustainable and convenient multi-modal transportation. This paper proposes a partition-based real-time network optimization model for the hybrid system that capable of (i)scales to a large number of trips; (ii) incorporates dynamic ride-sharing to MoD services and (iii)generates optimal routes for real-time demands. To enhance applicability, the proposed model accounts for transit frequency, waiting time, MoD vehicle capacity and fleet size, travel delay and operations cost for vehicles. Extensive experimental results show a significant reduction of vehicle empty miles and a boost to mobility enhancement.

#### 3 - Interoperable Smart Card Data Management in Public Mass Transit

Stefan Voss, Professor, University of Hamburg, Institute of Information Systems (IWI), Von-Melle-Park 5, Hamburg, 20146, Germany, Filip Covic

Due to a lack of shared practices of deployment, installation and application, smart ticketing is often built on proprietary specifications limiting their scope of integration and compatibility among each other. Therefore, interoperability in public mass transit has become a central aspect of e-ticketing. We develop a standardised process on how to handle smart card data in an interoperable environment. We present a unified approach where data mining tools and model applications can be tested and implemented in every region embedded in the integrated network. Our Interoperable Smart Card Data Chain provides a continuous procedure for standardised data handling and management.

## ■ MB32

North Bldg 222B

### Data-driven Freight Logistics

Sponsored: TSL/Freight Transportation & Logistics

Sponsored Session

Chair: Satya Sarvani Malladi, Georgia Institute of Technology, Atlanta, GA, 30318, United States

Co-Chair: Shahab Derhami, Georgia Tech, 755 Ferst Drive, NW, Atlanta, GA, 30332, United States

#### 1 - Algorithms for Travel Speed Prediction using Big Data Provided by Home Delivery Company

Maha Gmira, École Polytechnique de Montréal, Montreal, QC, Canada  
Maha Gmira, Canada Excellence Research Chair in Data Science for Real-Time Decision-Making, Montreal, QC, Canada,  
Michel Gendreau, Andrea Lodi, Jean-Yves Potvin

In an urban environment, vehicle speed and consequently travel time can be highly variable, capturing time-varying features when modeling travel speeds provide an immediate benefit to commercial transportation companies that distribute goods. We present a travel speed prediction methodology based on data collected from mobile location devices installed inside commercial delivery vehicles. An analysis is conducted using unsupervised learning to cluster data, dimensionality reduction techniques, imputation methods and a Long Short Term Memory neural network to forecast travel speeds.

#### 2 - Adoption of Electric Trucks in Freight Transportation

Osman Alp, University of Calgary, Haskayne School of Business, 2500 University Drive, Scurfield Hall 120, Calgary, AB, T2N1N4, Canada, Tarkan Tan, Maximiliano Udenio

We analyze a fleet management problem of a freight transportation company, which aims to adopt a fleet of sustainable vehicles in a finite planning horizon. In particular, we optimize the transformation of their fleet into a mixed fleet of electric and diesel trucks. Our model also optimizes for the choice of charging technology as well as the number of charging facilities and their capacities. The objective of the decision maker is to minimize the investment costs for vehicles and the charging infrastructure, and the carbon emission related costs. We present a numerical study to generate insights about how to facilitate and incentivize the adoption of sustainable vehicle technologies in practice.

**3 - Data-driven Dynamic Smart Locker Logistics**

Shahab Derhami, Georgia Tech-ISYE, 755 Ferst Drive, NW,  
Atlanta, GA, 30332, United States, Satya Sarvani Malladi,  
Louis Faugere, Benoit Montreuil, Chelsea C. White

We consider the problem of dynamic management of mobile locker storage on a multi-location network. We model the non-stationary uncertainty of demand for lockers in our problem and propose effective heuristic solution approaches.

**■ MB33**

North Bldg 222C

**Joint Session ORAM/CYBER: CyberManufacturing Systems: Emerging Challenges and Opportunities**

Emerging Topic: OR and Advanced Manufacturing  
Emerging Topic Session

Chair: Mohammed Shafae, Virginia Tech, Blacksburg, VA, 24061, United States

**1 - Challenges and Opportunities in Additive Manufacturing for Industry 4.0**

Bianca Maria Colosimo, Politecnico di Milano, Via La Masa, 1,  
Milan, I-20156, Italy

This contribution discusses opportunities and challenges for quality assessment, monitoring and control of Additive Manufacturing (AM) processes and products. Special attention is devoted to in-situ data gathering and modeling.

**2 - Advancing the Security of Cybermanufacturing Systems: Challenges and Opportunities**

Lee Wells, Western Michigan University, 2827 Daventry Ave.,  
Portage, MI, 49024, United States, Mohammed Shafae

As technology progresses, cyber-physical systems are becoming susceptible to a wider range of attacks. In manufacturing, these attacks pose a significant threat to ensuring products conform to their original design intent and to maintaining the safety of equipment, employees, and consumers. This talk discusses the importance of research and development of cyber-security tools specifically designed for manufacturing. A critical review of current research efforts will be presented as well as opportunities for the future of this emerging research area.

**3 - Blockchain in Manufacturing - A Critical Review**

Soundar Kumara, Pennsylvania State University, PA,  
United States, Qianyu Hu

Blockchain is becoming popular in several domains. In this talk we explore the technical foundations of Blockchain and their applicability in (big-M) manufacturing. We will discuss provenance, platforms and the relevance of blockchain. With specific example in manufacturing, we will explore the integrated use of blockchain-analytics and AI. We will address the questions on hyperledger and Ethereum platforms.

**■ MB34**

North Bldg 223

**11:00 - 11:45 SAS/11:45 - 12:30 Gurobi**

Vendor Demo Session

**1 - Building and Solving Optimization Models with SAS**

Edward P. Hughes, SAS Institute, Inc., Sas Institute Inc., Sas  
Campus Drive, Cary, NC, 27513, United States, Rob Pratt

SAS provides a broad and deep array of data and analytic capabilities, including data integration, statistics, data and text mining, econometrics and forecasting, and operations research. The SAS optimization, simulation, and scheduling features coordinate easily and fully with other SAS strengths in data handling, analytics, and reporting. OPTMODEL from SAS provides a powerful and intuitive algebraic optimization modeling language and unified support for building and solving LP, MILP, QP, NLP, CLP, and network-oriented models. And because the OPTMODEL optimization modeling language is contained within the OPTMODEL procedure, a SAS software module, it integrates seamlessly with the entire family of SAS functions, procedures, and macros. We'll demonstrate how you can use OPTMODEL to solve both basic and advanced problems, highlighting its newer capabilities and its support for both standard and customized solution strategies.

**2 - Advanced Heuristics with Gurobi**

Daniel Espinoza, Senior Developer, Gurobi Optimization,  
Houston, TX, United States

This talk covers one capability of MIP that is often overlooked: its ability to find and subsequently improve good quality solutions to exceedingly difficult problems. In particular, we will focus on techniques for using the Gurobi MIP solver as a heuristic, and a discussion on what makes a model more amenable to optimization.

**■ MB35**

North Bldg 224A

**Joint Session AAS/Practice Curated: AAS Best Student Presentation Competition II**

Sponsored: Aviation Applications

Sponsored Session

Chair: Susan Hotle, Virginia Polytechnic Institute and State University,

**1 - A Game-Theoretic Analysis of the Scaled Airline Preferences Mechanism for Airport Landing Slots**

Jackie W. Baek, Massachusetts Institute of Technology,  
77 Massachusetts Ave, Bldg E40-103, Cambridge, MA, 02139,  
United States

As arrival capacities increasingly constrain the air transportation system, there is a need for mechanisms by which airlines can exchange landing slots. Currently, when the number of aircraft is projected to exceed the capacity, flights are allocated slots in a first-scheduled-first-served manner. However, flights have different delay costs and can be assigned more efficiently. We focus on a reallocation mechanism called scaled airline preferences (SAP) and evaluate it on individual rationality, incentive compatibility, and fairness. The flight delay cost functions are scaled where the average unit delay cost by airline is equal and the mechanism minimizes the total scaled delay cost.

**2 - Forecasting Airport Transfer Passenger Flow Using Real-Time Data and Machine Learning**

Xiaojia Guo, University College London, International Hall,  
Lansdowne Terrace, London, WC1N 1AS, United Kingdom

Air passengers missing their connection can have a major impact on satisfaction and airline delays. Accurate forecasts of the flow of passengers and their journey times through an airport can help improve the experience of connecting passengers and support airline, airport, and air space punctuality. In collaboration with Heathrow Airport, we utilize real-time data to develop a predictive system based on a regression tree and Copula-based simulations. These real-time predictions can be used to inform target off-block time adjustments and determine resourcing levels at security and immigration.

**3 - An Assessment of the Potential Benefits of Dynamic Airline Scheduling**

Ahmet Esat Hızir, Massachusetts Institute of Technology,  
Cambridge, MA, United States,

The commonly used approach to airline schedule design does not enable airlines to effectively adapt to changes in passenger demand and airspace system capacity. This study investigates the potential benefits of a dynamic scheduling approach in which flight frequencies, schedules and aircraft types are finalized closer to the day of operations based on the most current demand information. Our integrated schedule design and fleet assignment model satisfies the passenger demand without inconveniencing passengers, to evaluate the maximum possible benefits of a dynamic scheduling strategy.

**■ MB36**

North Bldg 224B

**Resource Allocation in Capacity-constrained Airport Networks**

Sponsored: Aviation Applications

Sponsored Session

Chair: Konstantinos G. Zografos, Lancaster University, LA1 4YX, United Kingdom

Co-Chair: Alexandre Jacquillat, Carnegie Mellon University, Pittsburgh, PA, 15213, United States

**1 - A Passenger-centric Approach to Air Traffic Flow Management**

Alexandre Jacquillat, Carnegie Mellon University, Heinz College,  
5000 Forbes Avenue, Pittsburgh, PA, 15213, United States

Existing Air Traffic Flow Management (ATFM) approaches are based on aircraft-centric objectives. However, the ultimate impact of delays is amplified by passenger misconnections on connecting itineraries. We present a novel approach to flow management that balances flight delay costs with passenger delays. We develop a dual approach involving an analytical Markov Decision Process model and a large-scale integer optimization model. Results suggest that passenger disruptions can be greatly reduced through no, or limited, increases in flight delays, thus making the outcomes of ATFM initiatives more consistent with airline and passenger preferences. Implications for practice are discussed.



## 2 - Active Routing and Guidance Framework for Robust and Intelligent Taxiing

Jun Chen, Queen Mary University of London, London, United Kingdom, Michal Weizser

With increasing demand for air travel and overloaded airport facilities, inefficient airport taxiing operations are identified as a significant. An Active Routing and Guidance Framework is proposed for complex ground handling problems at major airports to reduce taxi times, operating costs and environmental impact. The problem is interdisciplinary and multi-dimensional as the efficiency of airport operations depends on aircraft dynamics, airport layout, air traffic, and other constraints. Results show that by considering all these factors in an integrated decision making framework the generated routing and guidance solutions are more realistic for pilots to follow, saving time and fuel.

## 3 - Dynamic Control of Airport Capacity Allocation with Stochastic Considerations

Robert Shone, Lancaster University, Lancaster, United Kingdom, Kevin D. Glazebrook, Konstantinos G. Zografos

The ever-increasing demand for air transport services continues to put the resources of the world's busiest airports under tremendous pressure. Many optimization models have been proposed for runway scheduling, aircraft sequencing and other problems related to air traffic flow management. In this talk we discuss how to develop new approaches which explicitly take into account uncertainty caused by weather conditions and other operational factors.

## ■ MB37

North Bldg 225A

## Machine Learning and Causality

Sponsored: Applied Probability

Sponsored Session

Chair: Nathan Kallus, Cornell University, New York, NY, 10044, United States

Co-Chair: Stefan Wager, Stanford GSB, Stanford GSB, New York, NY, 10023-2154, United States

### 1 - Interpreting Predictive Models for Human-in-the-loop Analytics

Hamsa Sridhar Bastani, Wharton School, Philadelphia, PA, United States, Osbert Bastani, Carolyn Kim

Interpretability has become an important issue as machine learning is increasingly used to inform consequential decisions. We propose an approach for interpreting complex blackbox models by extracting a decision tree that approximates the model. The algorithm avoids overfitting by actively sampling new training points using the blackbox model. We use this technique to interpret a random forest classifier for predicting diabetes risk. Physicians successfully used our interpretation to discover an unexpected causal issue in the diabetes classifier.

### 2 - Long Tail Phenomenon in Discrete Choice Estimation

Pu He, Columbia University, Uris Hall, Cub 4H, New York, NY, 10027, United States, Fanyin Zheng

Long tail distribution of sales or market share data is a common phenomenon in empirical studies in economics, operations, and marketing. Classic discrete choice estimation framework ignores the long tail and can lead to biased estimates. In this work, we introduce a new two-step procedure to solve the problem. Our solution applies machine learning algorithms to estimate market shares in the first stage, and in the second stage we estimate a weighted multinomial logit model to recover customer preference parameters. We show that our proposed approach corrects for the bias in demand estimates and improves profits when these estimates are used in pricing decisions.

### 3 - Learning to Personalize Safely Under Unobserved Confounding

Nathan Kallus, Cornell University, 2 W. Loop Road, # 316, New York, NY, 10044, United States

Recent work on counterfactual learning from observational data aims to leverage large-scale data — much larger than any experiment can ever be — to learn individual-level causal effects for personalized interventions. The hope is to transform electronic medical records to personalized treatment regimes, transactional records to personalized pricing strategies, and click- and “like”-streams to personalized advertising campaigns. Motivated by the richness of the data, existing approaches make the simplifying assumption that there are no unobserved confounders: unobserved variables that affect both treatment and outcome and would induce non-causal correlations that cannot be accounted for. However, all observational data, which lacks experimental manipulation, no matter how rich, will inevitably be subject to some level of unobserved confounding and assuming otherwise can lead to personalized treatment policies that seek to exploit individual-level effects that are not really there, may intervene where not necessary, and may in fact lead to net harm rather than net good relative to current, non-personalized practices.

## 4 - Quasi-oracle Estimation of Heterogeneous Treatment Effects

Stefan Wager, Stanford University, 655 Knight Way, Stanford, CA, United States, Xinkun Nie

Flexible estimation of treatment effects lies at the heart of many statistical challenges. We develop a class of algorithms for heterogeneous treatment effect estimation in observational studies. We estimate marginal effects and treatment propensities to form an objective function that isolates the causal signal. Then, we optimize this objective function. For both steps, we can use any loss-minimization method fine-tuned by cross validation. In the case of penalized kernel regression, we show that even if the pilot estimates for marginal effects and treatment propensities are not particularly accurate, we achieve the same regret bounds as an oracle who has a priori knowledge of them.

## ■ MB38

North Bldg 225B

## Joint Session APS/ENRE: Stochastic Modeling and Optimization for Energy Systems

Sponsored: Applied Probability

Sponsored Session

Chair: Adam Wierman, California Institute of Technology, Pasadena, CA, 91125, United States

Co-Chair: Alessandro Zocca, California Institute of Technology, Pasadena, CA, 91125, United States

### 1 - Power Grid State Estimation Following Cyber-physical Attacks

Saleh Soltan, Princeton University, NJ, United States, Mihalis Yannakakis, Gil Zussman, Prateek Mittal, H. Vincent Poor

I will provide a summary of our recent results on power grid state estimation following cyber-physical attacks in which an adversary attacks an area by: (i) disconnecting some lines within the attacked area, and (ii) blocking/modifying the measurements from monitoring devices within the area to mask the line failures. We demonstrate that by using tools from graph theory and by leveraging the algebraic properties of the power flow equations, one can detect the attacked area as well as line failures in polynomial time under some topological constraints on the area. I then show that stochastic version of these methods can be used to detect line failures efficiently in general attacked area topologies.

### 2 - Understanding the Inefficiency of Security-constrained Economic Dispatch

Enrique Mallada, Johns Hopkins University, 3400 N. Charles St, Barton Hall 312, Baltimore, MD, 21218, United States, Mohammad Hajiesmaili, Wuhan Desmond Cai

The security-constrained economic dispatch (SCED) problem tries to maintain the reliability of a power network by ensuring that a single failure does not lead to a global outage. In this talk, we analyze the economic cost of incorporating security constraints in economic dispatch. Inspired by inefficiency metrics in game theory, we introduce the notion of price of security as a metric that formally characterizes the economic inefficiency of SCED. We investigate the impact of generation availability and demand distribution on the price of security. Our results show that renewable sources, with nearly zero marginal costs, can have a high impact on the price of security.

### 3 - Robust Volt-var Optimization in Power Distribution Systems

Weixuan Lin, Cornell University, Ithaca, NY, United States, Eilyan Bitar

We consider the decentralized reactive power control of photovoltaic (PV) inverters spread throughout a radial distribution network. Our objective is to minimize the expected voltage regulation error, while guaranteeing the robust satisfaction of distribution system voltage magnitude and PV inverter capacity constraints in real-time. We provide a method to compute a robust decentralized controller via the solution of a finite-dimensional conic program. The resulting trajectories of PV inverter reactive power injections and nodal voltage magnitudes are guaranteed to be feasible for any realization of the system disturbance under the proposed control policy.

### 4 - Failure Localization in Power Systems via Tree Partitions

Alessandro Zocca, California Institute of Technology, 1200 E. California Blv, MC 305-16, Pasadena, CA, 91125, United States, Linqi Guo, Chen Liang, Steven Low, Adam Wierman

Cascading failures in power systems propagate non-locally, making the control and mitigation of outages extremely hard. Using the emerging concept of the tree partition, we provide a complete analytical characterization of line failure localizability in transmission networks. The crucial insight is that power systems that have more and thus smaller tree partition components are less vulnerable to large-scale outages. Furthermore, our characterization suggests that by switching off only a negligible portion of transmission lines we can have a significantly better control of cascading failures without significantly increase line congestion across the network.

## ■ MB39

North Bldg 226A

**Multi-armed Bandits and Reinforcement Learning**

Sponsored: Applied Probability

Sponsored Session

Chair: Shipra Agrawal, Columbia University, New York, NY, 10027, United States

**1 - Deep Exploration in Reinforcement Learning via Randomized Value Functions**

Daniel Russo, Columbia University

We propose the use of randomized value functions to guide systematic exploration in reinforcement learning. This offers an elegant means for synthesizing statistically and computationally efficient exploration with common RL algorithms like temporal-difference learning, which produce parameterized value function estimates. We present several RL algorithms that leverage randomized value functions and demonstrate their efficacy through computational studies. We also prove a regret bound that establishes statistical efficiency with a tabular representation.

**2 - Partition Identification using Multi-armed Bandit Methods with Applications to Financial Risk**Sandeep Juneja, Tata Institute of Fundamental Research,  
Homi Bhabha Road, Mumbai, Maharashtra, 400005, India,  
Subhashini Krishnasamy

Given a vector of probability distributions, each of which can be sampled independently, we identify the partition to which this vector belongs from a finitely partitioned universe using Bandit methods. We develop complexity bounds on expected number of samples needed for correct identification with high probability. Distributions are parametrized, and partitions primarily correspond to these parameters lying in half spaces, or more general convex sets or their complements. We propose algorithms that can match the lower bounds asymptotically with decreasing probability of error. Few applications associated with nested simulation and its applications to finance are discussed.

**3 - Bandits with Delayed Aggregated Anonymous Feedback**Shipra Agrawal, Columbia University, Industrial Engr and OR,  
423 S. W. Mudd Building, New York, NY, 10027, United States,  
Randy Jia

We study a variant of the stochastic K-armed bandit problem, which we call “bandits with delayed, aggregated anonymous feedback”. In this problem, when the player pulls an arm, a reward is generated, however it is not immediately observed. Instead, at the end of each round the player observes only the sum of a number of previously generated rewards which happen to arrive in the given round due to stochastic delays. We provide an algorithm that matches the worst case regret of the non-anonymous problem exactly when the delays are bounded, and up to logarithmic factors or an additive variance term for unbounded delays.

**4 - Near Optimal Policies for Dynamic Assortment Planning under MNL Models**Xi Chen, New York University, 44 W. 4th St, NYU KMC Room  
8-50, New York, NY, 10012, United States, Yining Wang,  
Yuan Zhou

In this talk, we consider the dynamic assortment selection problem under an uncapacitated multinomial-logit (MNL) model. Since all the utility parameters of customers are unknown, the seller needs to simultaneously learn customers’ choice behavior and make dynamic decisions on assortments based on the current knowledge. By carefully analyzing a revenue potential function, we proposed an efficient trisection algorithm that achieves an item-independent regret bound of  $O(\sqrt{T \log \log T})$ , which matches information theoretical lower bounds up to iterated logarithmic terms. We also provide experimental results to demonstrate the effectiveness of the proposed method.

## ■ MB40

North Bldg 226B

**Judgements and Forecasts**

Sponsored: Decision Analysis

Sponsored Session

Chair: Asa Palley, Indiana University, Bloomington, IN, 47405, United States

**1 - Incentive-Compatible Forecasting Competitions**Jens Witkowski, Frankfurt School of Finance & Management,  
Adickesallee 32-34, Frankfurt, 60322, Germany, Rupert Freeman,  
Jennifer W. Vaughan, David M. Pennock, Andreas Krause

We consider the design of forecasting competitions in which multiple forecasters make predictions about one or more independent events and compete for a single prize. Our primary objective is to incentivize forecasters to report truthfully, so that forecasts are informative and forecasters need not spend any cognitive effort

strategizing about reports. Proper scoring rules incentivize truthful reporting if all forecasters are paid according to their scores. However, incentives become distorted if only the best-scoring forecaster wins a prize. We introduce a truthful forecaster selection mechanism, and lower-bound the probability that our mechanism selects the most accurate forecaster.

**2 - The Effectiveness of Trimmed Prediction Polls in Time Series Forecasting Involving Structural Breaks**Shijith Kumar PM, PhD Candidate, IE Business School, Calle  
Maria De Molina, 12, Madrid, 280006, Spain, Matthias Seifert,  
Yun Shin Lee

Forecast combination literature emphasizes the need for detailed studies on aggregation and trimming. We introduce simple trimming rules to aggregate judgmental time series forecasts with structural breaks. While the extant literature explores aggregation of forecasts in stable environments, we focus on environments characterized by fundamental regime shifts. In an empirical study, we find that forecasters are sensitive to structural shifts in time series and are systematically biased depending on the direction of these shifts, making static trimming less applicable. We propose trimming approaches to factor in these biases to aggregate opinion pools under such unstable environments.

**3 - Aggregating Information from a Single Set of Predictions**

Ville Satopaa, INSEAD, 140 Avenue Daumesnil, Paris, 75012, France

Even though aggregating multiple predictions typically outperforms the average individual prediction, there is no consensus about the right way to do this. Optimally, an aggregator would use all the information in the predictions. Aggregation is particularly challenging when there is only one prediction per forecaster. In this work, we develop methodology for such a “one-shot” environment. Our aggregator relies on Bayesian statistics and produces a posterior distribution of the consensus aggregate. We illustrate the methodology on real-world and synthetic forecasting data.

**4 - Sport Obermeyer Revisited: From Points to Probabilities**Asa Palley, Indiana University, 1275 E. 10th St, Bloomington, IN,  
47405, United States, Casey Lichtendahl,  
Yael S. Grushka-Cockayne

We develop a procedure that a decision maker can use to estimate a predictive distribution for a variable of interest using only a single point estimate from each of a number of different experts, without having to elicit complete distributions. Given past collections of judgments and realizations, we propose a Bayesian method that can be used to estimate a probability distribution for the variable of interest using the mean and variance of the new collection of judgments. We examine the accuracy of the procedure with sets of real judgments about economic variables in the U.S. and Europe, finding that it provides comparable performance to the linear opinion pool of subjective probability distributions.

## ■ MB41

North Bldg 226C

**Behavioral Decision Analysis with Mortality and Health Outcomes**

Sponsored: Decision Analysis

Sponsored Session

Chair: Jeffery L. Guyse, California State Polytechnic University-  
Pomona, Pomona, CA, 91768, United StatesCo-Chair: L. Robin Keller, University of California, Irvine, University of  
California-Irvine, Irvine, CA, 92697-3125, United States**1 - Valuing Sequences of Lives Lost or Saved Over Time: Preference for Uniform Sequences**Jeffery L. Guyse, Professor, California State Polytechnic University-  
Pomona, 3801 West Temple Avenue, Pomona, CA, 91768,  
United States, L. Robin Keller, Candice Huynh

We present our within-subject survey using subjective ratings for sequences of lives lost or saved over time, with factors embedded for anomalies. The prediction results for the standard discounting model (SDM) are analyzed. A model by Loewenstein & Prelec (L&P) for valuation of sequences was then fit to the survey data and compared to the best fits of the SDM. In all cases, the L&P model performed better than the SDM at predicting the individual normalized ratings for these sequences. We conclude that preferences for uniform sequences should be considered in policy making, rather than presuming people have a preference for declining sequences of mortality outcomes.

## 2 - Lives Saved vs. Lives Lost in Survey Research: Investigating Methodological Consistency

Candice Huynh, California State Polytechnic University, Pomona, College of Business, TOM, 3801 W. Temple Ave, Pomona, CA, 91768, United States, Jeffery L. Guyse, L. Robin Keller

Seven different elicitation procedures are employed in a between-subjects experiment over hypothetical scenarios involving lives either being saved or lost over time. Inspired by a study by Frederick (2003) which included lives being saved in 6 of the 7 procedures (choice, matching, total, sequence, equity, & context) and lives lost in just one of the cases (rating), we incorporate a completely balanced and symmetrical design with both lives saved and lives lost for all 7 methodologies. The effect on the survey responses due to the outcome being saved or lost along with the contextual effect of the questionnaire design itself are both analyzed for each of the 7 elicitation procedures employed.

## 3 - Psychophysics of Terror Attack Consequences

Matthew Baucum, University of Southern California, 12540 Braddock Drive, Apt 105, Los Angeles, CA, 90066, United States, Heather Rosoff, Richard S. John

We conceptualize public perception of the consequences of severe biological and radiological terror attacks along three dimensions: size of spatial area impacted, length of time of impact, and fatalities. We conducted an experiment in which respondents (n=384) read a vivid scenario about either a biological or radiological terror attack, varying in terms of spatial area impacted, length of time of impact, and fatalities. We develop psychophysical curves for all 3 consequence dimensions in terms of perceived attack severity, perceived risk, and reported fear. These curves are markedly non-linear, and in some cases, non-monotonic.

## 4 - The Effects of Assigning Buddies on Social Support in Online Communities

Ali Esmaeeli, University of California, Irvine, 1914 Verano Place, Irvine, CA, 92617, United States, Cornelia Pechmann

We look at the effects of assigning buddies on the social support that participants receive in an online community. We show that an active buddy provides more social support than another active community member. We also show that an inactive buddy doesn't decrease a person's engagement with others in the community. We develop four continuous and quantitative tie-strength measures to evaluate the level of participants' engagement with others in online communities. These measures are quite general and can be used to evaluate tie-strength in other online communities.

## ■ MB42

North Bldg 227A

## Simulation Optimization I

Sponsored: Simulation

Sponsored Session

Chair: Wie Xie, RPI

### 1 - An Envelope Procedure for Ranking and Selection Problems

Shane Henderson, Cornell University, Ithaca, NY, 14853, United States, Sijia Ma

We present the envelope procedure for solving ranking and selection problems, aka exploratory bandit problems. We assume that each system (or arm) can be repeatedly sampled independently, and returns a subGaussian random variable. We prove that the envelope procedure returns a selected system that is within a given distance (in mean) of the best system with given probability. We also present a complexity analysis and computational results showing that the envelope procedure has impressive empirical performance under a specific sampling rule.

### 2 - Distance Correlation Screening for Hierarchically Structured Data

Ilya Ryzhov, University of Maryland, College Park, MD, 20742, United States, Yimei Fan, Yuan Liao

In many applications of business and marketing analytics, common characteristics of products and customers are represented as categorical variables, and each category can be split up into multiple subcategories at a lower level of the hierarchy. Hundreds of thousands of binary variables may be used to model the hierarchy, which makes it very useful to screen out large numbers of irrelevant or insignificant variables. We propose a new dynamic screening method that screens out large parts of the hierarchy at higher levels, greatly reducing the computational burden of screening and producing much more powerful predictive models. This approach may be useful in other areas, such as simulation analytics.

## 3 - A Metamodel-assisted Framework for Two-stage Optimization via Simulation

Wei Xie, Rensselaer Polytechnic Institute, 110 8th Street, CII, Room 5207, Troy, NY, 12180, United States, Yuan Yi

For the discrete two-stage optimization with the unknown response obtained from simulation, we introduce a metamodel-assisted framework that can efficiently employ the simulation resource to iteratively solve for the optimal first- and second-stage decisions. At each visited first-stage decision, we develop a local metamodel to solve a set of deterministic recourse problems simultaneously. Then, we construct a global metamodel accounting for the finite sampling error from SAA and the second-stage optimality gap. Assisted by this global-local metamodel, we propose a simulation optimization approach that can efficiently guide the search for the optimal first- and second-stage decisions.

## ■ MB43

North Bldg 227B

## Emerging Topics in Energy Systems Integration

Emerging Topic: Energy and Climate

Emerging Topic Session

Chair: Dharik Mallapragada, ExxonMobil Corporate Strategic Research, ExxonMobil Corporate Strategic Research, Annandale, NJ, United States

### 1 - Evaluating Tradeoffs in Modeling Approaches for Electric Power Systems Analysis

Nidhi Santen, Electric Power Research Institute, Palo Alto, CA, United States, John Bistline

Throughout electric power systems analysis, simplifying assumptions and approaches are required to make models computationally tractable while still representing salient features of the system. The objective of this research is to test and examine the benefits of alternate modeling approaches in four key areas: temporal resolution, spatial resolution, representation of end use, and representation of uncertainty. We calculate and examine potential impacts of using simplified methodologies in these areas via a set of exercises using the U.S. long-range electric generation capacity planning model, US-REGEN.

### 2 - Emerging Topics in Energy Systems Integration Vehicle Electrification

Matteo Muratori, National Renewable Energy Laboratory

From an energy perspective, transportation is the least diversified demand sector, and offers numerous untapped opportunities for electrification over the next decades. While petroleum is still the major fuel used in transportation, adoption of electric vehicles in the light-duty vehicle market is increasing and electrification of other sub-sectors is gaining more interest. Vehicle electrification is creating new connections between the transportation and the electric sectors and coordinated charging is the greatest near-term opportunity for synergistic integration of electric vehicles in the power system and exploit vehicle flexibility to support grid operation.

### 3 - Impact of Model Resolution on Scenario Outcomes for Electricity Sector System Expansion

Dharik Mallapragada, ExxonMobil Research and Engineering, 1545 Route 22 East, Annandale, NJ, 08801, United States, Dimitri Papageorgiou, Aranya Venkatesh

Power sector capacity expansion models (CEMs) assess how techno-economic and policy drivers impact the cost-optimal generation capacity mix and their utilization over decadal time scales. Here, we evaluate the impact of incorporating operational detail in a CEM on the resulting outputs for various Texas grid scenarios. In general, we find that a traditional CEM with aggregated time blocks, overstates solar capacity and understates wind and natural gas capacity compared to an alternate CEM with chronological time-representation of grid operations. The findings imply the need for embedding sufficient temporal resolution and chronology in CEMs and broadly multi-sector energy-economic models

### 4 - The Role of Firm Low-carbon Electricity Resources in Deep Decarbonization of Power Generation

Nestor A. Sepulveda, Massachusetts Institute of Technology, Cambridge, MA, 02142, United States

We use a detailed power system investment and operations model to investigate the role of firm low-carbon resources in decarbonizing power generation in combination with variable renewable resources, energy storage, demand flexibility, and long-distance transmission interconnections. To increase the robustness of our results, we evaluate nearly 1000 cases covering a range of emissions limits, regional differences in demand and renewable resource potential, and a wide range of technology and cost uncertainties.



## ■ MB44

North Bldg 227C

**Joint Session ENRE/Practice Curated: Applications of Conic Optimization for Energy Systems**Sponsored: Energy, Natural Res & the Environment/Electricity  
Sponsored Session

Chair: Ramtin Madani, The University of Texas at Arlington, Arlington, TX, 76015, United States

**1 - Multiplier-based Observer Design for Large-scale Lipschitz Systems**

Ming Jin, UC Berkeley, Cory 406, Berkeley, CA, 94720, United States

Observer design for nonlinear systems with incomplete state observations is of practical significance. To this end, this study presents a multiplier-based approach that is capable of determining an asymptotically stable observer for a large class of highly nonlinear and large-scale systems. Both the present and the state-of-the-art methods are evaluated in a benchmark example and a case study on the dynamic power system state estimation, where the proposed approach exhibits an imperative trade-off between non-conservatism and computational tractability, establishing its viability for real-world large-scale nonlinear systems.

**2 - Sequential Convex Relaxation for Optimal Power Flow and Unit Commitment Problems**

Ramtin Madani, The University of Texas at Arlington, Arlington, TX, 76015, United States, Fariba Zohrizadeh, Mohsen Kheirandishfard, Adnan Nasir, Edward Quarm

This talk is concerned with the optimal power flow (OPF) and unit commitment (UC) problems. We propose a novel convex relaxation, which transforms non-convex AC power flow equations into convex quadratic inequalities. Additionally, we propose a penalization technique which guarantees the recovery of feasible solutions for the original non-convex problem, under certain assumptions. The proposed penalized convex relaxation scheme can be used sequentially in order to find feasible and near-globally optimal solutions. By solving a few rounds of penalized convex relaxation, fully feasible solutions are obtained for challenging benchmark test cases with as many as 13659 buses.

**3 - Convex Relaxation of Bilinear Matrix Inequalities with Applications to Optimal Control Synthesis**

Mohsen Kheirandishfard, The University of Texas at Arlington, Arlington, TX, United States, Fariba Zohrizadeh, Muhammad Adil, Ramtin Madani

This talk is concerned with the problem of minimizing a linear objective function subject to a bilinear matrix inequality (BMI) constraint. We introduce a family of convex relaxations which transform BMI optimization problems into polynomial-time solvable surrogates. The efficacy of the proposed convex relaxation methods are demonstrated on benchmark instance of optimal control synthesis problems.

**4 - A Mixed-integer Programming Solution to AC Optimal Transmission Switching for Load Shed Prevention**

William Eric Brown, Texas A&amp;M University, College Station, TX, United States, Erick Moreno-Centeno

Optimal transmission switching (OTS) has garnered recent consideration for its value in leveraging the flexibility of the power grid. However, solving the AC-OTS problem remains quite difficult in practice. We propose a mixed-integer linear programming (MILP) model for the AC-OTS to maximize post-contingency load shed prevention (LSP). Unlike the widely-used DC-OTS, which is based on the standard DC linearizations (i.e., the DCOPF), our model produces LSP values which are highly correlated with the ACOPF. In thorough computational tests, our approach identifies the AC optimal switch in over 92% of studied instances.

## ■ MB45

North Bldg 228A

**Solving Deterministic Security Constrained Unit Commitment Problem**Sponsored: Energy, Natural Res & the Environment/Electricity  
Sponsored Session

Chair: Feng Pan, Pacific Northwest National Laboratory, Richland, WA, 99352, United States

Co-Chair: Yonghong Chen, Midcontinent ISO, 720 City Center Drive, Carmel, IN, 46032, United States

**1 - Heuristics for Unit Commitment Models**

Zonghao Gu, Gurobi Optimization, Houston, TX, United States, Edward Rothberg

When solving unit commitment MIP models, the majority of the optimality gap in the early part of the search process is due to the quality of the initial feasible

solutions. This presentation will consider a number of heuristic schemes for producing better solutions quickly. We'll present computational results for the most effective approaches.

**2 - Develop Smart Heuristics to Generate Hints for Solving Security Constrained Unit Commitment**

Yonghong Chen, Midwest ISO, 720 City Center Drive, Carmel, IN, 46032, United States

This presentation discusses using problem specific smart heuristics to generate hints to speed up the process to solve security constrained unit commitment. These heuristics can generate hints to reduce large number of variables and constraints. Using parallel computing to improve the hints will also be discussed.

**3 - HIPPO - A HPC Solver for Security Constrained Unit Commitment Problem**

Feng Pan, Pacific Northwest National Laboratory, 902 Battelle Boulevard, Richland, WA, 99352, United States, Jesse Holzer, Yonghong Chen, Edward Rothberg, Jie Wan, Ralf Elbert

HIPPO is a software library for solving the security constrained unit commitment (SCUC) problem. The goal of HIPPO is to reduce the solution time for solving SCUC in ISO/RTO day-ahead energy markets. The team is developing a concurrent optimization solver consisting of several algorithmic approaches such as branch-and-bound, decomposition methods and market based heuristics. These algorithms are implemented to Leverage high-performance computing clusters to further improve the algorithm performance. This talk will provide an overview of the HIPPO project, funded by ARPA-E, and the HIPPO software which includes SCUC models, algorithms and their performance.

**4 - Performance Comparison of Security Constrained Unit Commitment Formulations**

Yanan Yu, University of Florida, 321 University Village, Apt 3, Gainesville, FL, 32603, United States, Yongpei Guan

Following a significant expansion of power systems, the large-scale security constrained unit commitment (SCUC) has been an important and challenging problem in recent years. Several formulations have been developed in existing literature, characterizing SCUC problems in various aspects and resulting in diverse computational efficiency. In this presentation, we aim to find the key factors to improve the tightness of SCUC formulation by performance comparison. The relationship of decision variables in alternative formulations are derived and their tightness is analyzed. A suggested formulation is given at last.

## ■ MB46

North Bldg 228B

**Energy Markets**Sponsored: Energy, Natural Res & the Environment/Energy  
Sponsored Session

Chair: Felipe A. Feijoo, Pontificia Universidad Catolica de Valparaiso, Chile,

**1 - Compressor Optimization in Gas Networks**

Pascal Van Hentenryck, University of Michigan, 1813 IOE Building, 1205 Beal Avenue, Ann Arbor, MI, 48108-2117, United States

The talk presents an optimization approach to the optimal control of compressors in gas networks. The optimization model captures the gas dynamics in these networks and is shown to be applicable to medium-sized networks, while producing results that have been verified by state-of-the-art simulations.

**2 - The Effects of Possible Tax Credit Policy Withdrawal on Timing and Size of Green Investment**

Roel Nagy, Norwegian University of Science &amp; Technology, Trondheim, Norway

This paper analyses the effect of policy uncertainty on investment timing and investment size of a renewable energy project, and the interaction between both. We find that increasing the probability of withdrawal increases the incentive to invest now and decreases the optimal investment size. A firm that invests at the timing threshold value invests at larger scale when the policy is not in effect than when it is in effect. An investor maximising social welfare has the same timing as the profit-maximizing monopolist, but invests at twice the investment size.

**3 - Optimizing the Operations and Design of Concentrating Solar Power for Day Ahead Markets**

Michael J. Wagner, National Renewable Energy Laboratory, 15013 Denver West Pkwy, MS-RSF033, Golden, CO, 80401, United States

Concentrating solar power (CSP) systems include thermal storage, which can be dispatched on demand to a power cycle to produce electricity during desirable times of the day. Developers of CSP plan new facilities that will operate in a range of international markets, each having unique characteristics that often variably incentivize power production on a diurnal or seasonal basis. A CSP plant can successfully exploit market features, given an holistic dispatch scheduling program and favorable design characteristics. We present final results from a multi-year project that has developed techniques and software for concurrently optimizing CSP plant design, dispatch, and operations.

**4 - The Value of Turning-point Detection for Optimal Investment**

Lars Sendstad, Norway, Michail Dimitriou

Understanding the evolution of business cycles is key for investment in renewable energy, since alternative energy technologies are associated with periods of economic growth whose duration depends on disruptive innovations and market saturation. We develop a regime-switching, real options model that facilitates time-varying transition probabilities in order to capture the evolution of economic indicators, and utilize a numerical approach to approximate the value of the investment opportunity. Results indicate that, ignoring the evolution of transition probabilities can result in severe valuation errors.

**■ MB47**

North Bldg 229A

**Joint Session Tutorial/Practice Curated:  
Tabu and Scatter Search: Principles and Practice**

Emerging Topic: Practice Curated Track

Emerging Topic Session

Chair: Rong Pan, Arizona State University, School of Computing Informatics & Decision Sys, P.O. Box 878809, Tempe, AZ, 85287-8809, United States

**1 - Tabu and Scatter Search: Principles and Practice**

Manuel Laguna, University of Colorado, Boulder, CO, United States

This tutorial focuses on the metaheuristics known as tabu search and scatter search. Tabu search has dramatically changed our ability to solve a host of problems in applied science, business, and engineering. The adaptive memory designs of tabu search have provided useful alternatives and supplements to the types of memory embodied in other metaheuristic approaches. We also explore the evolutionary approach called scatter search, which originated from strategies for creating composite decision rules and surrogate constraints. Numerous studies have demonstrated the practical advantages of this approach for solving a diverse array of optimization. Scatter search contrasts with other evolutionary procedures, such as genetic algorithms, by providing unifying principles for joining solutions based on generalized path constructions and by utilizing strategic designs where other approaches resort to randomization. Additional advantages are provided by intensification and diversification mechanisms that exploit adaptive memory, drawing on foundations that link scatter search to tabu search. We show connections between tabu search and scatter search by demonstrating how they can be applied to many optimization problems found in practice. This tutorial also discusses the search strategy called path relinking, relevant to both tabu and scatter search. Features added to both tabu and scatter search by extension of their basic philosophy are captured in the path relinking framework. From a spatial orientation, the process of generating linear combinations of a set of reference solutions (as typically done in scatter search) may be characterized as generating paths between and beyond these solutions, where solutions on such paths also serve as sources for generating additional paths. This leads to a broader conception of the meaning of creating combinations of solutions. By natural extension, such combinations may be conceived to arise by generating paths between and beyond selected solutions in the neighborhood space. Finally, we highlight key ideas and research issues associated with tabu search, scatter search, and path relinking that offer promise of yielding future advances.

**■ MB48**

North Bldg 229B

**Environment and Sustainability**

Sponsored: Energy, Natural Res &amp; the Environment Environment &amp; Sustainability

Sponsored Session

Chair: Sandra D. Eksiöglu, Clemson University, Clemson, SC, 29634, United States

**1 - A Stochastic Biomass Blending Problem**

Berkay Gulcan, Clemson University, Clemson, SC

Blending biomass of different physical or chemical properties provides an opportunity to passively adjust the quality of the feedstock to meet the specifications of the conversion platform. We propose a chance constraint optimization model to identify the mix of biomass to optimize the performance of the Thermochemical conversion process. Chance constraints ensure that process requirements are met most of the time, despite the stochastic nature of biomass availability and quality. Our numerical analyses compare process performance under centralized and decentralized decision making framework.

**2 - Gender-based Selection Strategy for Improving Response in Genomic Selection**

Guiping Hu, Iowa State University, 3014 Black Engineering, Ames, IA, 50011, United States, Megan Wellner, Saba Moeinazade, Lizhi Wang

Genomic selection is a technique that breeders use to select plants or animals to mate and produce new generations of species. We propose a gender-based selection strategy, which was inspired by how two genders of wild animals take different roles in fighting for food and caring for their offspring. Our selection approach selects individuals with the highest short-term achievement as male, and then select individuals that are the most complementary to the male. We will present simulation results that compare the performance of the new approach against the state-of-the-art approaches in the literature.

**3 - Economic Evaluation of Biofuel Production in Hot Spots Identified for Hydroclimatic Sustainability**

Nathan Parker, Assistant Professor, Arizona State University, 800 South Cady Mall, Tempe, AZ, 85281, United States, Nazli Uludere Aragon

The sustainability of the spatial configuration of bioenergy crop production in the US is evaluated for economic and hydroclimatic impacts using a location-allocation model for biofuel industry linked to results of hydroclimatic model and a crop growth model. Converting existing land uses to bioenergy crops can reduce near-surface temperatures but pose a risk of excessive water withdrawals. A system that provides local cooling without a reduction in soil moisture that can support a biofuel industry is found in two regions of the country.

**■ MB49**

North Bldg 230

**Planning Models in the Petrochemicals Sector**

Sponsored: Energy, Natural Res &amp; the Environment/Natural Resources Petrochemicals

Sponsored Session

Chair: Ajit Gopalakrishnan, Air Liquide, Newark, DE, 19702, United States

**1 - Pooling Problems under Perfect and Imperfect Competition**

Dimitri Papageorgiou, ExxonMobil Research &amp; Engineering, 1545 Route 22 East, Annandale, NJ, 08886, United States, Francisco Trespalacios, Stuart Harwood

We investigate pooling problems in which multiple players vie with one another to maximize individual profit in a competitive market. Each player controls a processing network involving intermediate tanks (or pools) where raw materials are blended together before being further combined into final products. Each player then solves a pure or mixed-integer bilinear optimization problem whose profit is influenced by other players. We present several bi-level formulations and numerical results of a novel decomposition algorithm.

**2 - A Large-scale MILP for Shale Gas Development Planning**

Nathan Blandino, EQT Corporation, 625 Liberty Avenue, Suite 1700, Pittsburgh, PA, 15222, United States, Markus Gustav Drouven

No abstract available

**3 - An Integrated International Oil and Gas Supply Model**

Tuncay Ugur Alparslan, U.S. Department of Energy, Washington, DC, 20009, United States

To improve its analytic capabilities, The U.S. Energy Information Administration (EIA) is currently upgrading its primary modeling tool for its projections for international energy markets, which is used to produce the annual International Energy Outlook (IEO), which provides valuable information to policy makers and other stakeholders. These efforts include simulating the global hydrocarbon supply via a new upstream integrated resource model, a new refining model, and a logistics network model. Combined, these three make up the new Global Hydrocarbon Supply Model (GHySMo). Scenario analysis using preliminary results from the integrated model will be the focus of this talk.

**4 - The New Role of Norwegian Gas in Europe**

Asgeir Tomasgard, Norwegian University of Science and Technology, Dept. of Industrial Economics, Alfred getz vei 3, Trondheim, 7491, Norway, Vegard Skonseng Bjerketvedt, Rudolf Gerardus Egging

The European energy system is in a restructuring process where large investments in intermittent renewable power generation are made. The volume of gas exported from the Norwegian continental shelf is foreseen to decrease. The changes in capacity and demand may open new commercial opportunities. Short-term and long-term uncertainties will affect how to maximize the value of Norwegian gas and contribute to the restructuring of the green energy system. We will use multi-horizon stochastic programming to analyze solutions related to capacity services based on Norwegian natural gas exports.

## ■ MB50

North Bldg 231A

**Behavioral Aspects of Project Management**

Emerging Topic: Behavioral Aspects of OR

Emerging Topic Session

Chair: Lin Wang, PhD, Chinese Academy of Sciences, Beijing, China

**1 - Modeling Human Behaviors in Project Management: A Systematic Review**

Lin Wang, Chinese Academy of Sciences, Beijing, 100190, China

To successfully implement projects, the significant role of “humans cannot be ignored. Stakeholders (project managers, senior managers, etc.), who make vital decisions alongside the project life cycle, are often influenced by behavioral biases and inducing great losses. These losses are observed as the project escalation phenomenon in the project management (PM) literature for decades, while some behavioral decision-making models have been built by operational research (OR) experts. This paper makes a systematic review of the literature originating from both communities, and discusses the why, the what and the how of the behavioral modeling to facilitate wise project decisions.

**2 - Pricing Strategies Based on Consumers' Shopping Preference for Sales Channels**

JieYu Lei, Northwestern Polytechnical University, Xi'an, Shaanxi, China, Ada Che

E-commerce brings two new sales channels: online direct channel(ODC) and online retail channel(ORC) into market, which help consumers no longer stick to traditional offline channel (TOC) to buy what they need. In this paper, we mainly focus on how manufacturers make their pricing strategies when they adopt two or three channels to sell their products. According to the Stackelberg game theory, we design a sale model considering consumers' preference for different channels and calculate the optimal pricing strategies of manufacturers and retailers. The result shows that the optimal price of a product in ODC is generally higher than that of the same product in ORC and TOC.

**3 - Human Capital, Technological Progress and Structural Unemployment**

Chao Li, Shandong University, 180 Wenhuxi Road, Weihai, 264209, China

Technology progress makes old skills abundant, eliminate relevant job opportunities and create new job vacancies at the same time, thus threatening a rise in structural unemployment. The simulation results demonstrate that the quantity of structural unemployment brought about by technological progress is determined by the inequality of human capital. The more severe inequality of human capital in the labor force, the more people with lower human capital whose old skills will be replaced by new technologies, which are developed by those with higher human capital. Therefore, technology progress may not necessarily cause high structural unemployment.

**4 - Network of Factors Influencing Green Buildings Performance from Perspectives of Stakeholders**

Du Qiang, Chang'an University, School of Economics and Management, Middle-Section of Nan'er Huan Road, Xi'an, Shaanxi, 710064, China, Bai Libiao, Huang ning, Wang Hailing

To accelerate the process and improve the efficiency of promoting green buildings in China, this paper filtrate 28 green building influence factors from 2-perspective of life cycle and stakeholders. And a questionnaire survey of 20 green building experts was used in social network for recognize quantitatively the critical influence factors. This paper filled the gap of previous research on green building that rarely measure the relationship between different influence factors in the project life cycle. Final, remarks include policy recommendations for promotion green building in China and suggestions for future research.

**5 - Project Managers' Paradoxical Leader Behavior in Construction Project Teams: Effects on Team Adaptation and Project Performance**

Wenqian Guo, Tianjin University, Building 25A, Tianjin University, No.92, Weijin Road, Nankai District, Tianjin, Tianjin, 300072, China

Research on paradoxical leader behavior developed in the organizational field, has not been given adequate attention to the area of construction project management. Using a paradoxical lens, the empirical analysis of a survey of 187 Chinese general contractors clearly indicates that there is a positive relationship between project managers' paradoxical leader behavior and construction project performance. Moreover, this relationship is mediated by team adaptation. The findings have significant theoretical and managerial implications for effective construction project management.

## ■ MB51

North Bldg 231B

**Managing Risk in Complex Projects**

Emerging Topic: Project Management and Scheduling, in Memory of Joe Leung,

Emerging Topic Session

Chair: Gary Mitchell, University of Portland, Pamplin School of Business, Portland, OR, 97203, United States

**1 - Improving Outsourcing Project Estimation**

Richard Kraude, University of Buffalo, Buffalo, NY, United States, Enno Siemsen, Sriram Narayanan

Outsourcing is common, unfortunately, so too are delays in outsourced projects. Selecting outsource partners that will meet deadlines requires accurate estimation of the effort it will take to complete them. We conduct a behavior experiment to test how project planning differs for external estimates and how to improve them.

**2 - Measuring a Project's Schedule Performance: Earned Duration and Beyond**

Mikhail Gordon, University of Pittsburgh, Pittsburgh, PA, 15224, United States, Tim Lowe, Richard Wendell

This paper gives some new results on Earned Duration, including a characterization of how scheduling metrics based on Earned Duration behave in late-finishing and early-finishing projects, and an explanation with examples on why it is susceptible to giving false negatives and false positives in measuring a project's scheduling performance. The paper then notes how Critical Path methodology, when used appropriately, can by itself effectively assess and communicate schedule status of a project.

**3 - Do Incentive Contracts Coordinate Decentralized Projects?**

Theodore D. Klastorin, University of Washington, ISOM Department, Box 353226, Seattle, WA, 98195-3226, United States, Shi Chen, Michael Wagner

We consider a serial decentralized project where a client subcontracts the work to an independent contractor. Using a Stackelberg game, we analyze a general class of incentive contracts and show that setting the due date to zero defines an optimal contract for the client. Furthermore, we show that this contract coordinates the project under certain conditions.

**4 - Optimizing a New Product Development Project**

Gary Mitchell, University of Portland, Pamplin School of Business, Portland, OR, 97203, United States, Theodore Klastorin

An innovator firm is planning to start a new product development project consisting of  $n$  sequential stages or subprojects and learns of a rumor that an unknown competitor may enter the market with a competing product. Wishing to maximize the expected benefits of the new product, the innovator firm must decide how to respond to this potential competitive threat. We consider the optimal product introduction timing and the time-cost tradeoffs associated with accelerated project costs and market potential.

**5 - Robust Management Optimization of a Portfolio of Interdependent Projects**

Marcus V. Poggi, Prof, PUC-Rio - Pontificia Universidade Catolica do Rio de Janeiro, Rua M. S. Vicente 225, Rio de Janeiro, 22591-900, Brazil, Carlos Raoni Mendes, Bruno Flach

Determining optimal activity execution modes and risk mitigation plans for a portfolio of interdependent projects subject to multiple sources of uncertainty are objects of this work. We model the uncertain environment as an adversary that selects worst-case combinations of risks for any action. Next, we present a robust optimization model and its reformulation scheme. The resulting model is solved by a cut-generation. Experiments over instances derived from PSPLIB are reported. They show how important integrated resource allocation decisions is when dealing with portfolios of interdependent projects. They also highlight the effectiveness and computational feasibility of the method.



## ■ MB52

North Bldg 231C

### Social Media and Information Warfare

Emerging Topic: Social Media Analytics

Emerging Topic Session

Chair: Tauhid Zaman, Ph.D., MIT, Cambridge, MA, 02139, United States

#### 1 - Detecting Influence Campaigns in Social Networks using the Ising Model

Nicolas Guenon des Mesnards, MIT, Boston, MA, United States, Tauhid Zaman

Recent news about Russian propaganda bots influencing elections has given the bot detection problem new importance. This problem can be modeled using the Ising model from statistical physics. This allows for joint detection of multiple bots. We show that the problem reduces to a max-flow problem, allowing for an efficient solution. We find that our bot-detection algorithm is able to find bots more accurately than existing state of the art methods. Our analysis of the bot tweets suggests that they are engaged in coordinated influence campaigns.

#### 2 - Time Varying Opinion Dynamics with Stubborn Agents

David S. Hunter, Massachusetts Institute of Technology, Cambridge, MA, 02139, United States

We propose a social network opinion dynamics model where individuals grow more stubborn with time. We are able to prove several results on the convergence of the opinions. Depending upon how fast individuals become stubborn, the opinions may never converge, converge in mean, or converge in probability. We provide a precise characterization of these different convergence conditions. We also find that when the opinions converge, the equilibrium opinions are given by a linear system which has a form similar to Ohm's Law from circuit theory.

#### 3 - Optimizing Influence Campaigns with Stubborn Agents

Tauhid Zaman, MIT, MA, United States

Often there is a need to run an influence campaign in a social network. This can be done using "stubborn agents who shift the opinions of non-stubborn people. We use an Ohm's Law equilibrium condition for the opinions as the basis for an integer program for the optimal placement of the agents. We prove that this problem is submodular, allowing for accurate greedy solutions. Using several simulated and real network topologies, we show that a small number of agents can have a strong influence on the population.

## ■ MB53

North Bldg 232A

### Matching Theory I

Sponsored: Auction and Marketing Design

Sponsored Session

Chair: Thayer Morrill, North Carolina State University, Raleigh, NC, 27695, United States

#### 1 - Obvious Manipulations

Thayer Morrill, North Carolina State University, Campus Box 8110, Raleigh, NC, 27695, United States, Peter Troyan

Game theory is based on the idea that if an agent has the incentive to deviate, then she will do so. However, it is clear that not all incentives to deviate are the same. How much higher of a payoff does the agent realize from deviating? Does a deviation expose the agent to more risk? Does it require a great deal of information to know whether or not a deviation will be profitable? For some mechanisms there is clear evidence that agents are adept at identifying opportunities for manipulation in practice, while for others, though opportunities for manipulation exist, they are observed much less frequently. This paper seeks a simple and tractable method for determining when a mechanism is easy to manipulate.

#### 2 - Efficient and Pretty Fair Course Assignment with Quotas

Stefan Waldherr, Technische Universität München, Boltzmannstr 3, Room 01.10.054, Munich, 85748, Germany, Martin Bichler, Alexander Hammerl, Thayer Morrill

We focus on course assignment problems with minimum and maximum quotas. It is well known that even without minimum quotas there does not exist a strategyproof mechanism that always selects an efficient and fair assignment. While the extended seats TTC mechanism (ESTTC, i.e. TTC incorporating minimum quotas) satisfies strategyproofness and efficiency for minimum quotas, it is very unfair and leads to many instances of justified envy. In this talk, we present extensions to ESTTC which satisfy weak fairness axioms. Further, we leverage field data from a large-scale course assignment application where we can show a significant reduction of justified envy when applying our mechanisms.

#### 3 - Revenue from Matching Platforms

James Schummer, Northwestern University, 2211 Campus Dr, Evanston, IL, 60208, United States, Philip Marx

We consider matching platforms on which agents form pairs. The platform commits to a stable matching mechanism, charging fees to both sides. Agents on the short side of such markets capture more value than those on the long side (Ashlagi et al. 2017). Nevertheless we show that the platform does not price discriminate between the sides based on their relative sizes. We demonstrate that the cost of committing to stability vanishes in large markets. While preference correlation leads the platform to bias its prices in imbalanced markets, we show that the direction of price bias depends on the type of correlation; these effects are absent from models of two-sided markets without capacity constraints.

#### 4 - On Finding Stable and Efficient Solutions for the Team Formation Problem

Robert Day, University of Connecticut, 2100 Hillside Road U-1041, Storrs, CT, 06269-1041, United States, Hoda Atef Yekta, David Bergman

We study a mathematical-programming approach to team formation, focused on the interplay between two of the most common objectives considered in the related literature: economic efficiency (i.e., the maximization of social welfare) and game-theoretic stability (e.g., finding a core solution when one exists). With a weighted objective across these two goals, the problem is modeled as a bi-level binary optimization problem, and transformed into a single-level, exponentially sized binary integer program. We then devise a branch-cut-and-price algorithm and demonstrate its efficacy through an extensive set of simulations, with favorable comparisons to other algorithms from the literature.

## ■ MB54

North Bldg 232B

### Opportunities and New Directions for Behavioral OM

Sponsored: Behavioral Operations Management

Sponsored Session

Chair: Anyan Qi, The University of Texas at Dallas, Richardson, TX, 75080, United States

Co-Chair: Ruth Beer, Indiana University, Kelley School of Business, Indiana University, Kelley School of Business, Bloomington, IN, 47404-5180, United States

#### 1 - Opportunities for Behavioral Research within Supply Chain Management

Tava Olsen, University of Auckland, ISOM, Business School, University of Auckland, Auckland, 1142, New Zealand

This talk examines opportunities for behavioral research within supply chain management (broadly defined). In particular, I will discuss models and empirical anomalies that could benefit from behavioral research (in terms of lab experiments, behaviorally inspired modelling, or empirical research). The talk concludes with a discussion my perception of the role for behavioral research going forward.

#### 2 - Consumer Behavior in Pricing Applications

Georgia Perakis, Massachusetts Institute of Technology, Sloan School of Management, MIT, 100 Main Street Rm E62-565, Cambridge, MA, 02142-1347, United States

In recent years, there has been increasing interest in incorporating behavioral phenomena in Operations Management applications. In particular, in this talk, I will discuss some recent work on pricing applications where amending the traditional models to include consumer behavior (such as memory and anchoring effects) leads to interesting new insights.

#### 3 - Queueing Systems with (MIS)behaving Servers and Customers

Mor Armony, New York University, 44 West 4th Street #8-62, New York, NY, 10012, United States

Traditional queueing theory has assumed that customer arrival times and service requirement as well as server service speed are exogenously determined. This assumption makes sense for systems with non-human customers and servers. In practice, in service systems that involve humans as customers and / or servers, behavioral effects may lead to violation of these assumptions. Specifically, both customers and servers may respond to incentives related to social comparisons, sense of ownership, and fatigue, to name a few. These behaviors can dramatically change the performance and optimal control of queueing systems. We survey recent literature and present opportunities for further research.

## ■ MB55

North Bldg 232C

**Advancing Diversity of Women in STEM**

Sponsored: Women in OR/MS (WORMS)

Sponsored Session

Chair: Sudharshana A. Apte, Altria Client Services, Richmond, VA, 23221, United States

**1 - Four Things Women in Data Science Can Learn from*****Game of Thrones***

Jennifer Priestley, Kennesaw State University, Kennesaw, GA, United States

Studies consistently find that women are underrepresented in most computational disciplines - particularly in Analytics and Data Science. And although events and organizations that encourage girls K-12 to learn to code have increased over the last few years, the number of college-age women in computational disciplines has not increased. Nor has the proportion of women in analytical leadership positions. In this talk, one of the few female directors of a Ph.D. in Data Science will provide perspective on how the discipline can attract (and retain) more female talent. These points will be framed through the popular HBO Series Game of Thrones.

**2 - Unintended Consequences of Increasing Female Engineers' Representation in Managerial Roles**

Teresa Cadrador, University of Illinois at Urbana Champaign, Champaign, IL, United States

Engineering remains one of the most highly and persistently sex segregated occupations in the US. Though the extant literature submits that women's increased access to managerial positions in male-dominated occupations should represent an important strategy for addressing sex segregation, my recent research suggests that women's representation in managerial roles in engineering may promote the very sex segregation it is attempting to mitigate. I will present the results of two field studies which highlight how and why female engineers' movement into managerial roles fosters a form of intra-occupational sex segregation with unintended (and largely negative) consequences for women.

**3 - Advancing Diversity: Ideas for Faculty Searches**

Karen Smilowitz, Northwestern University, Industrial Engineering Management Scienc, 2145 Sheridan Road RM D239, Evanston, IL, 60208, United States

In this talk, I will present related research, tips and lessons learned to advance diversity in STEM through more structured faculty searches.

## ■ MB56

West Bldg 101A

**HAS Distinguished Scholar Lecture Sanjay Mehrotra**

Sponsored: Health Applications

Sponsored Session

Chair: Ebru Korular Bish, Virginia Tech, Blacksburg, VA, 24060, United States

Co-Chair: Tinglong Dai, Johns Hopkins University, Johns Hopkins University, Baltimore, MD, 21202, United States

**1 - Big Data Analytics and Operations Research Modeling: Broader Implications of Lessons Learned from a Journey towards Influencing Policy Change in Organ Transplant**

Sanjay Mehrotra, Northwestern University, Dept of I. E. / M. S. C246 Tech Inst, 2145 Sheridan Road, Evanston, IL, 60208-3119, United States

As health applications scientists we excel in model development and establishing their properties. We will reverse this order. We will start with data and its analysis to establish the problem. We will next search for natural evidence to direct model development. We will need to establish our credibility among stake holders. Only now we can develop optimization models that leverage OR insights. But, they have to outperform an existing proposal through dominance on multiple metrics. It is now time to give up optimality, to help increase solution acceptability. Insights will lead us to developing novel multi-objective ambiguous optimization methodologies. This will be done using organ transplant as a case study. The newly developed methodologies and modeling paradigms have wide applications.

## ■ MB57

West Bldg 101B

**Disease Modeling and Decision-support Tools for Medical Decision Making**

Sponsored: Health Applications

Sponsored Session

Chair: Ethan Mark, Georgia Tech, Atlanta, GA, 30363, United States

Co-Chair: Pinar Keskinocak, Georgia Institute of Technology, Atlanta, GA, 30332, United States

**1 - An Empirical Analysis of the Opioid Prescription Epidemic**

Alireza Boloori, Arizona State University, Tempe, AZ, 85283, United States, Soroush Saghaian, Stephen Traub

Opioid epidemic has been largely attributed to the overprescription of opioid painkillers. As a result, many medical guidelines have recently urged healthcare providers to lessen opioid prescriptions in their medical practices. This, however, could negatively affect those patients who suffer from acute or chronic pain symptoms. Utilizing commercial insurance claims and encounters data, we first analyze the trade-off between the opioid epidemic and pain management. Based on our results, we then provide recommendations for both policymakers and healthcare providers.

**2 - Predictive Modeling of Multiple Chronic Conditions Development**

Adel Alaeddini, University of Texas at San Antonio, Department of Mechanical Engineering, One UTSA Circle, San Antonio, TX, 78249, United States

Development of multiple chronic conditions follows a complex process, influenced by several factors including the inter-relationship of the existing conditions, patient-level risk factors, etc. Using a large retrospective dataset of patient population, we build a machine learning model to explore the patterns of multiple chronic conditions development.

**3 - Computer-aided Diagnostic Models for Breast Cancer Screening and Diagnosis**

Oguzhan Alagoz, University of Wisconsin-Madison, 3242 Mechanical Engineering Building, 1513 University Avenue, Madison, WI, 53706, United States

Mammography is used for early breast cancer screening & diagnosis whereas mammography interpretation a difficult task due to similarities between early signs of breast cancer and normal structures in images. We have developed computer-aided diagnostic models and tested them using real-life data from private mammography databases. In this presentation, we describe our experiences, list the limitations of the existing CADx models, and provide possible future research directions.

**4 - Leveraging TCGA Gene Expression Data to Build Predictive Models for Cancer Drug Response**

Toyya Pujol, Georgia Institute of Technology, Atlanta, GA, 30318, United States, Evan Clayton, Peng Qiu

Personalized oncology promises to increase the success rate of cancer drug therapy by using molecular tumor profiles to determine the optimal therapeutic for an individual. Here, we build machine learning models using gene expression data directly from patients' primary tumor tissues to predict whether a patient will respond positively or negatively to a given drug. We show our models predict, with up to 86% accuracy, whether a patient will be a responder or not, and discuss how our findings may aid oncologists with making critical treatment decisions.

**5 - Using Machine Learning and Simulation to Compare Increased Organ Transplant Survival to Waiting for a Non-Increased Risk Organ**

Ethan Mark, Georgia Tech, 213 16th Street, NW, Apartment 4, Atlanta, GA, 30363, United States

Abstract not available.

## ■ MB58

West Bldg 101C

### Improving Healthcare Accessibility and Performance

Sponsored: Health Applications

Sponsored Session

Chair: Yong-Hong Kuo, The University of Hong Kong, Pokfulam Road, Hong Kong

#### 1 - Location Model with Patient Choices and Care Facility Attractiveness

Taesik Lee, KAIST, 291 Daehak-ro, Yuseong-gu, Daejeon, 305-701, Korea, Republic of, Kyosang Hwang

Addressing health care needs of medically underserved areas is an important public health task. One solution is to establish care capacities in the underserved areas, and naturally this involves a location decision. To maximize the effectiveness of the investment, it is important for a location model to consider patients' choice behavior to reflect future, expected use of new capacities. We present a location model with patient choice behavior in which care facilities' attributes are integrated as decision variables. In addition to location decisions, the model determines the attributes of new facilities, providing additional levers to improve accessibility in the medically underserved areas.

#### 2 - Physician Staffing and Shift Scheduling at Emergency Departments with Time Varying Productivity

Alireza Sabouri, Haskayne School of Business, University of Calgary, 2500 University Dr. NW, SH132, Calgary, AB, T2N 1N4, Canada, Negar Ganjoughighi, Marco Bijvank

Productivity of servers in service systems can decrease during a shift. This variable productivity alongside the stochastic nature of number of arrivals to the system, create a mismatch between demand and the number of customers that can be served by the scheduled servers during a particular period of time. In this study, we propose a two-step stochastic formulation for the staffing and shift scheduling problem with the objective of minimizing this mismatch. Numerical experiments are performed with data from a Canadian emergency department. The results show that the schedule generated by our formulation results in lower mismatch. We then evaluate the schedules by a simulation model.

#### 3 - Simulation Analytics of Hospital Emergency Department Operations

Yong-Hong Kuo, Assistant Professor, The University of Hong Kong, Dept. of Industrial and Manu. Sys. Eng., The University of Hong Kong, Pokfulam Road, Hong Kong, Janny M. Y. Leung, Colin Graham

This talk presents our work which uses simulation to analyze patient flows in a hospital emergency department (ED) in Hong Kong. This simulation approach provides a tool for the operations manager in the ED to assess the impact of changes in the system on the daily operations. We will discuss how simulation can be integrated into an optimization algorithm to aid decision-making. We will also present insights into managing ED operations derived from the simulation experiments.

#### 4 - Appointment Scheduling with No-shows and Multiple Types of Patients

Jingyao Huang, PhD Student, The University of Texas at Austin, 2110 Speedway, Austin, TX 78705, Austin, TX, 78705, United States, Douglas Morrice, Diwakar Gupta

We consider an appointment scheduling problem with heterogeneous patients under no-shows. We have two types of patients. One is the regular patient who visits the clinic in person and has no-show behavior. The other is Virtual Medicine (VM) patient who receives service via e-visit and has a time window, within which they'll be called and served. We first study a static model of assigning VM patients given regular patients' schedule to maximize the expected profit. We partially characterize the optimal schedule and then extend the model to the sequential scheduling problem with random service time. Finally, we propose a heuristic to solve the problem quickly and effectively.

## ■ MB59

West Bldg 102A

### Incentives for Optimal Treatment

Sponsored: Health Applications

Sponsored Session

Chair: Greg Zaric, Ivey Business School, London, ON, N6G 0N1, Canada

Co-Chair: Greg Critchley, Ivey Business School, London, ON, N6L0B2, Canada

#### 1 - Incentives for Optimal Coordination in Multi-payer Health Care Systems

Gregory Critchley, Western University-Ivey Business School, 10 Blodale Circle, Delaware, ON, N0L1E0, Canada, Lauren Cipriano, Greg Zaric, Jeremy D. Goldhaber-Fiebert

Multi-payer health care systems are common. For example, in the United States, many individuals are covered under private or employer-sponsored health plans prior to age 65 and are thereafter covered under Medicare. We model a multi-payer health care system using a Markov decision process and show that the penultimate payer, within a patient's lifetime, will prescribe treatment sub-optimally. We find that there exists a coordinating transfer payment between payers that results in a socially optimal treatment plan. Using the hepatitis C virus in a numerical example, we quantify the impact of a non-coordinated multi-payer health care system.

#### 2 - Sounding the Alarm on Opioids

Margret V. Bjarnadottir, University of Maryland, 4353 Van Munching Hall, College Park, MD, 20742-0001, United States, David Anderson, Ritu Agarwal, Kenyon Crowley, Kislaya Prasad, Alan Nelson

The ongoing opioid epidemic is a serious public health issue. In our paper, we investigate the feasibility of early detection of chronic opioid use and build advanced machine learning models that can be incorporated into clinical decision support systems, potentially minimizing adverse events associated with chronic opioid use and dependency.

#### 3 - Appointment Access in Family Medicine Clinic

Vera Tilson, University of Rochester, 3-343 Carol Simon Hall, W. E. Simon Graduate School of Business, Rochester, NY, 14627, United States, Ryan Spurr

We discuss a scheduling approach to improve access in a family medicine clinic.

#### 4 - Personalized Risk Management Strategies for Women at High Risk of Developing Breast Cancer and the Role of Adherence

Caglar Caglayan, Georgia Institute of Technology, 755 Ferst Drive NW, Atlanta, GA, 30332, United States, Turgay Ayer, Kalyan Pasupathy, Sandhya Pruthi

Women with BRCA 1/2 gene mutations or family history are at higher risk for breast cancer. The risk management interventions for high-risk women include intensified screening, preventive surgery (e.g., mastectomy) and risk-reducing medications (i.e., chemoprevention). Individual factors such as breast density and adherence behavior play a critical role at identifying and tailoring the optimal risk-management strategies for individuals at high-risk. In this work, we study breast cancer risk management problem with a comprehensive simulation model and identify optimal personalized strategies for high-risk individuals considering key patient characteristics and adherence behavior.

## ■ MB60

West Bldg 102B

### Managing Cost and Quality in Healthcare

Sponsored: Health Applications

Sponsored Session

Chair: Ozlem Yildiz, University of Virginia, Darden School of Business, United States

#### 1 - Fair Machine Learning with Health Data

Mahbod Olfat, PhD Student, University of California-Berkeley, 1433 Dwight Way, Unit C, Berkeley, CA, 94702, United States, Anil Aswani

The explosion of big data in health care has given warrant for concern about proliferation of bias and inefficient delivery of health care through machine learning methods. While researchers have begun to study this problem for supervised learning problems, it has been less well-explored under the paradigm of unsupervised learning. In this talk, we discuss fairness in the context of dimensionality reduction via principal component analysis (PCA). We present a definition of fairness and develop a convex SDP program that can achieve it. We conclude by showing how our approach can be used to perform a fair (with respect to age) clustering of health data that may be used to set health insurance rates.

#### 2 - Does Mandatory Overtime Law Improve Quality? Staffing Decisions and Operational Flexibility of Nursing Homes

Susan F. Lu, Purdue University, Krannert 441, West Lafayette, IN, 47907, United States, Lauren Lu

During the 2000s, over a dozen U.S. states passed laws that prohibit healthcare employers from mandating overtime for nurses. Using a nationwide panel data set from 2004 to 2012, we find that these mandatory overtime laws reduced the service quality of nursing homes, as measured by an increase in deficiency citations. This outcome can be explained by two undesirable changes in the staffing hours of registered nurses: decreased hours of permanent nurses and increased hours of contract nurses per resident day.



### 3 - Bundled Payments, Fee-for-service, and Competition: Implications on Quality and System Performance

Zheng Han, University of Kansas, Lawrence, KS, 66049,  
United States, Mazhar Arkan, Suman Mallik

We study the quality competition between two hospitals where one under the fee-for-service (FFS), while the other under the bundled payment (BP). The demand, the costs, and the probability of successfully treating a patient depends on the hospital's chosen quality. Under such a setting, we develop a game theoretic model to answer the following questions. Is BP (FFS) payment scheme always associated with high (low) equilibrium quality? What factors affect the equilibrium outcomes and how? What insights can a policymaker (i.e., an insurer) obtain from the equilibrium quality outcomes?

### 4 - Scheduling Smarter and Working Harder: The Key to Reducing Turnover

Kevin Mayo, Indiana University, 1275 E. 10th St, Bloomington,  
IN, 47405, United States, Eric Webb, Kurt M. Bretthauer,  
George Ball

Turnover rates among nurse aides in skilled nursing facilities is extremely high and likely to get worse as demand outpaces supply. Such turnover rates have significant negative effects on patient health outcomes and various costs associated with turnover. We examine the scheduling characteristics of 6,634 part time nurse aides and 5,305 turnovers to determine how scheduling policies affect turnover. We identify the impacts of the amount, variation, and type of scheduling that all significantly influence the likelihood of turnover, and the differential effects in high or low workload environments. Using these insights, managers can better schedule their nurse aides to reduce turnover.

## ■ MB61

West Bldg 102C

### Stochastic Models in Healthcare

Sponsored: Health Applications

Sponsored Session

Chair: Oguzhan Alagoz, University of Wisconsin-Madison,  
Madison, WI, 53706, United States

Co-Chair: Ali Hjaar, Wisconsin-Madison, Wisconsin-Madison, WI,  
United States

### 1 - Optimizing Hospital Resources to Improve Care Delivery -An Application to Bed Capacity

Eva Lee, Georgia Tech, Industrial & Systems Engineering, Ctr for  
Operations Research in Medicine, Atlanta, GA, 30332-0205,  
United States

We consider the problem of partitioning clinical services in hospitals into groups with the goal of efficiently allocating existing inpatient beds. We derive a 2-stage approach stochastic approach to address the 3-fold problem: 1) how many groups of services to form; 2) how many beds to allocate to each group; and 3) how to partition services among the groups. Three full-scale examples will be presented to demonstrate the flexibility and diverse application of our framework with managerial insights for different utility optimization goals and queueing systems.

### 2 - Optimizing Breast Cancer Screening using Partially Observable Markov Decision Processes

Ali Hajjar, University of Wisconsin-Madison, 1513 University  
Avenue, 3233 Mechanical Engineering Building, Madison, WI,  
53706, United States, Oguzhan Alagoz

Breast cancer, the leading cause of cancer death for women, can be detected at earlier stages through mammography screening. Therefore, We formulate a finite-horizon, partially observable Markov decision process (POMDP) model for this problem.

### 3 - Optimal Defibrillator Deployment versus Actual Deployment

Timothy Chan, University of Toronto, Mechanical and Industrial  
Engineering, 5 Kings College Road, Toronto, ON, M5S 3G8,  
Canada, Christopher Sun

Public defibrillators, which are located throughout cities worldwide, can be used to resuscitate cardiac arrest victims by bystanders with no training. However, location decisions to date are not data-driven. In this talk, we present a head-to-head comparison of optimal defibrillator locations against actual defibrillator locations using nine years of real data. At every decision epoch, the optimization model can only make decisions based on past data. On out-of-sample, future cardiac arrests, the optimization model improves spatiotemporal coverage, a measure of spatial proximity to cardiac arrests and temporal accessibility of the defibrillator, by 50-100% compared to actual location decisions.

### 4 - A Data-driven Stochastic Programming Approach to the Outpatient Colonoscopy Scheduling Problem

Karmel Shehadeh, University of Michigan, 1205 Beal Avenue,  
Ann Arbor, MI, 48105, United States, Amy Cohn

We present a data-driven stochastic programming approach to optimize scheduling templates for stochastic colonoscopy procedures. Particular attention is paid to the underlying impact of pre-colonoscopy bowel preparation on variability in colonoscopy duration and the competing schedule metrics, including patient delays, clinic overtime, and colonoscopy procedure outcomes. A case study based on an outpatient procedure center (OPC) at a large medical center is used to draw some useful managerial insights for OPC managers.

## ■ MB62

West Bldg 103A

### Decision Making and Data Mining

Sponsored: Data Mining

Sponsored Session

Chair: Michael Lash, University of Iowa, Iowa City, IA

### 1 - Hybrid Decision Making: When Interpretable Models Collaborate with Black-box Models

Tong Wang, University of Iowa, Pappajohn Business Build,  
21 East Market Street, Iowa City, IA, 52245, United States

Interpretable machine learning has received increasing interest especially in domains where humans are involved in the decision-making process. However, the possible loss of the task performance for gaining interpretability is often inevitable. We propose a novel framework for building a Hybrid Decision Model that integrates an interpretable model with any black-box model to make better decisions. We design a principled objective function that considers predictive accuracy, model interpretability, and data explainability. Experiments show that hybrid models do not necessarily trade accuracy for explainability and provide higher flexibility in model designing.

### 2 - ELM-SOM: A Continuous Self-Organizing Map for Visualization

Renjie Hu, University of Iowa, 1505 W. Benton Street, Iowa City,  
IA, 52246, United States, Venous Roshdibenam, Hans J. Johnson,  
Emil Eirola, Anton Akusok, Yoan Miche, Kaj-Mikael Björk,  
Amaury Lendasse

This paper presents a novel dimensionality reduction technique: ELM-SOM. This technique preserves the intrinsic quality of Self-Organizing Maps (SOM): it is nonlinear and suitable for big data. It also brings continuity to the projection using two Extreme Learning Machine (ELM) models, the first one to perform the dimensionality reduction and the second one to perform the reconstruction. ELM-SOM is tested successfully on six diverse datasets. Regarding reconstruction error, ELM-SOM is comparable to SOM while bringing continuity.

### 3 - Text Mining of Online Reviews using Deep Learning Techniques

Asil Oztekin, University of Massachusetts Lowell, 333 1st Street,  
Unit 210, Lowell, MA, 01850-2580, United States

In this study, we used deep learning techniques to analyze user-generated content, particularly online text reviews of travelers who describe their experience of airports and suggest a recommendation for other travelers. By performing aspect-oriented sentiment analysis on the user reviews, we develop a holistic predictive approach. The study reveals that aspect-oriented sentiment scores significantly improve the predictive power for the recommendation decision of the user. Recurrent Neural Network based deep learning approach performed superior to other machine learning models in predicting customer recommendations. This research has methodological, application-based, and managerial implications.

## ■ MB63

West Bldg 103B

### Joint Session DM/AI/Practice Curated: From Data to Algorithms: How Ride-sharing Platforms Improve Rider and Driver Experiences?

Sponsored: Data Mining

Sponsored Session

Chair: Helin Zhu, UBER

Co-Chair: Peter Frazier, Cornell University, School of Operations Research, and Information Engineering, Ithaca, NY, 14853, United States

#### 1 - Driver Preferences at Uber: Welfare, Flexibility, and Pricing

Peter Frazier, Cornell University, School of Operations Research, and Information Engineering, Ithaca, NY, 14853, United States

The Uber platform lets drivers set preferences for trips going to a destination through its Driver Destination feature. This feature lets drivers avoid deadheading when they need to go home, but also creates gaming opportunities by letting drivers select lucrative long trips. Moreover, when many drivers use this feature, their reduced flexibility causes riders going to unpopular destinations to wait longer on pickups for drivers coming from further away. We study the impact on welfare of this and other similar preference-setting features in two-sided markets. We show that they can decrease welfare when launched without discretion, but improve welfare when combined with appropriate pricing.

#### 2 - Dynamic Pricing and Matching in Ride-hailing Platforms

Helin Zhu, Marketplace Optimization, Uber, 1455 Market Street, 4th Floor, San Francisco, CA, 94103, United States, Chiwei Yan, Dawn Woodard, Nikita Korolko

Advanced matching and dynamic pricing algorithms are the two key levers in ride-hailing platforms. We demonstrate via a stylized model, calibrated with real data, that the synergy of these two levers can bring significantly more benefits. Specifically, we study a novel matching mechanism called dynamic waiting. We show that pricing and waiting could be jointly optimized in reducing rider and driving waiting times, lowering price volatility, and increasing trip volume and welfare.

#### 3 - Estimating Primary Demand in Bike-sharing Systems

Chong Yang Goh, Massachusetts Institute of Technology-ORC, Cambridge, MA, 02139-4910, United States, Chiwei Yan, Patrick Jaillet

We consider the problem of estimating the primary or first-choice demand for a bike-sharing service using trip and inventory data. To account for choice substitutions, we propose a rank-based demand model that treats each observed trip as the best available option in a latent ranking over origin-destination pairs. We then solve a high dimensional estimation problem using algorithms that (i) find sparse representations of the parameters efficiently, and (ii) constrain trip substitutions spatially according to the bike-share network. Our method is effective in recovering the primary demand and computationally tractable on a city scale, as we demonstrate on a bike-sharing service in Boston.

## ■ MB64

West Bldg 104A

### Joint Session DM/Practice Curated: Data Science and Analytics in Supply Chain

Sponsored: Data Mining

Sponsored Session

Chair: Aihong Wen, Walmart

#### 1 - Reinforce Learning with Counterpetition Strategy in Hotelling Model

Xiaoya Xu, Assistant Professor, Guangdong University Of Finance & Economics, 21 Luntou Road, Guangzhou 510320, Guangdong, P.R. China, Guangzhou, 510320, China

The combination of reinforce learning and game theory is exceptional serviceable for solving complexity problems, we adapt this methodology to the cooperation game in hotelling model. Assuming customers apply their potential game in each stage for maximizing their optimal revenue. Using the reinforce learning, customers can automatically choosing their optimal strategy systematically .

#### 2 - Improving Demand Forecast Accuracy through Partial Aggregation

Vladimir Kovtun, Assistant Professor, Yeshiva University, 500 W. 186th Street, New York, NY, 10033, United States, Avi H. Giloni, Sridhar Seshadri, Hurvich Clifford

We consider a single firm (retailer) that observes demand streams coming from many distinct consumer populations. We assume that each demand stream follows an Autoregressive Moving Average (ARMA) process. We show with

examples that by grouping similar ARMA demand streams together and forecasting several partial-aggregate streams the retailer is able to drastically improve its forecast accuracy when compared to grouping all consumer streams together and forecasting a single aggregate ARMA stream. Furthermore we show that little is lost when compared to forecasting all demand streams separately.

#### 3 - Spatial Patterns and Socioeconomic Dimensions of Short-term Shared Accommodations: The Case of Airbnb in Los Angeles and New York City

Avijit Sarkar, Professor, University of Redlands, 1200 E. Colton Avenue, Redlands, CA, 92373, United States, Mehrdad Koohikamali, James B. Pick

This study examines spatiotemporal aspects and socioeconomic dimensions of shared accommodations within the broader context of the sharing economy. Specifically, we examine how socioeconomic attributes of Airbnb hosts moderated by hosts' attitudes towards trust and greener consumption influence participation in the sharing economy. Spatial bias in sharing economy participation rates is examined and policy implications for the supply side of shared accommodations are discussed along with generalizability of results for two major U.S. cities - New York City, NY and Los Angeles CA.

#### 4 - Cognitive Learning with Application to Supply Chains

Seho Kee, Arizona State University, Tempe, AZ, 85044, United States, Ghazal Shams, Mani Janakiram, Mark A. Wilkinson, George Runger

The evolving data-rich environment has enabled making data-driven business decisions. Rather than traditional approaches, more automated, adaptive, and intelligent systems can be developed to expand upon the capabilities of human decision makers. A cognitive computing approach is presented to learn and improve human decision-making in a dynamic, context-aware decision support platform. The proposed system is applied to a real-world use case in supply chain.

#### 5 - Sourcing Model Optimization using a Linear Model in Multi-echelon Distribution Network

Prashant Kaldindi Verma, FleetPride, Inc., 600 E. Las Colinas Blvd #400,, Irving, TX, 75039, United States, Mohit Arora, Homarjun Agrahari, Brian Steinmiller, Ziyu Li

The SKU sourcing policy can have significant impact on the transportation and inventory holding costs. We developed and implemented an optimization model that explicitly deals with vendor contracts, varying pack sizes and demand. The model takes into account the cost of transportation to each location and handling cost specific to location. We will present mathematical model, and financial impact it has had on the organization.

## ■ MB65

West Bldg 104B

### Joint Session DM/Practice Curated: Data Science and Applied Probability

Sponsored: Data Mining

Sponsored Session

Chair: Xu Sun, Columbia University, New York City, NY, 10027, United States

#### 1 - Shepherding the Herd

Ville Satopaa, INSEAD, 140 Avenue Daumesnil, Paris, 75012, France, Jussi Keppo

We analyze multiple agents who forecast an underlying dynamic state based on a stream of public and private signals. Each agent minimizes a convex combination of her forecasting error and deviation from the other agents' forecasts. As a result, the agents exhibit herding behavior - a bias that has been well-recognized in the literature. We first derive and analyze the agents' optimal forecast under different levels of herding. This extends the Kalman filter to applications where herding is an important part of the process. After that we solve a dynamic strategy that allows a social planner to influence the agents' forecasting and this way raise welfare through disclosure of public information.

#### 2 - Determining Optimal Treatment Allocations for Online Experiments with a Fixed Number of Rounds

Balaji PitchaiKannu, Research Scholar, IIT Madras, 236, Bhadra Hostel, IIT Madras, IIT Madras, CHENNAI, 600036, India, Nandan Sudarsanam

In this study, we determine the optimal treatment allocation for experiments that are conducted in batches, in a live setting with a finite horizon. Unlike the traditional online learning problems seen in the multi-armed Bandit setup, our problem statement requires that the entire trial horizon is exhausted in a fixed set of rounds. In this environment, we determine the batch size as well as the ratio of treatments to units for each round. Our optimization seeks to minimize expected cumulative regret, a common metric in online learning. We use a Bayesian framework to model the theoretical means of the alternatives and the noise in the system as Gaussian distributions.

**3 - Predicting and Managing Sustainability**

Kemal Gursoy, Professor, Rutgers University, 100 Rockefeller Road,  
Room 5146, Piscataway, NJ, 08854, United States

In order to survive we must learn how to predict and manage the change in our environment and ourselves. This brings an immense challenge of collecting facts and extracting sufficient information from this incoming stream of big data. In this work, we identify some significant challenges in this process and present an adaptive method for managing sustainability.

**4 - Many-server Service Systems with Autoregressive Inputs**

Xu Sun, Columbia University, New York City, NY, 10027,  
United States

Motivated by recent studies revealing the presence of significant autocorrelation and overdispersion in arrival data at large call centers, we study a class of queueing systems where customers arrive according to a doubly stochastic Poisson point process whose intensities are driven by a time-dependent Cox-Ingersoll-Ross (CIR) process. The nonnegativity and autoregressive feature of the CIR process makes it a good candidate for modeling temporary dips and surges in arrivals. We study asymptotic performances such as the queue length and customer delays. The results acknowledge the presence of autoregressive structure in arrivals and produce operational insights into staffing decisions.

**■ MB66**

West Bldg 105A

**Joint Session AI/Practice Curated:  
Healthcare Analytics and Medical Decision-making**

Sponsored: Artificial Intelligence

Sponsored Session

Chair: Karthik Srinivasan, University of Arizona, Tucson, AZ, 85719,  
United States

**1 - A Prediction Model for Adverse Events in Hospitalized Patients**

Yu-Kai Lin, PhD, Georgia State University, Atlanta, GA,  
United States, Xiao Fang

Inadequate patient safety is a serious problem in current medical practice. Medical errors cause adverse events (AEs) among patients and lead to increased hospital stays, medical costs, and risk of death. This study develops a novel in-hospital AE prediction method to improve patient safety. We evaluate the predictive performance and practical utility of the proposed method using real-world inpatient data. Our results suggest that the proposed model can better predict and prevent in-hospital AEs than alternative methods.

**2 - Study for Out-of-hospital Days in Chinese Cancer Patients**

Luwen Huangfu, 1549 N. Santa Rita, Tucson, AZ, 85719,  
United States

Cancer readmission time interval, or Out-of-Hospital Days (OHD) between two consecutive hospital admissions, has been widely adopted as an important measure of healthcare service. However, there is a paucity of models that focus on OHD and associated risk factors. We aim to utilize OHD that is more than 30 days as the result of cancer patient's personal and medical conditions and treatment costs. We analyze a sample of 635,261 cancer inpatients Electronic Health Records (EHR) from 190 hospitals in China. Using hierarchical linear regression, we show that age, marital status, previous admissions and whether the treating hospital is in the same province as the patient, are significant factors in OHD.

**3 - Predicting High Cost Patients at Point of Admission using  
Network Science**

Karthik Srinivasan, University of Arizona, Tucson, AZ, 85721,  
United States, Sudha Ram, Faiz Currim

Data mining models for high-cost patient encounter prediction at the point-of-admission (HPEPP) in inpatient wards are scarce in literature due to lack of availability of relevant features at such an early stage of treatment. We explore a disease co-occurrence network (DCN) for community formation and structural properties to create new input features for HPEPP models. We propose community membership and high-cost propensity scores as two network based features for HPEPP modeling. We find that our proposed set of features improve performance of prediction models. HPEPP model using our feature set has the potential to reduce overall health care expenditure in US.

**■ MB67**

West Bldg 105B

**Consumer Behavior & Firm Strategies in e-Platforms**

Sponsored: Information Systems

Sponsored Session

Chair: Gang Wang, University of Delaware

**1 - Impact of Contest Structure on Crowdsourcing Performance  
and Outcome**

Yuan Jin, University of Connecticut, 19A Hillside Circle, Storrs, CT,  
06268, United States, Shun-Yang Lee, Sulin Ba, Jan Stallaert

A crowdsourcing project can be conducted in either a sequential contest or a simultaneous contest. A sequential contest launches multiple sub-contests, each of which focuses on one task of the project. In contrast, a simultaneous contest requires contestants to finish all the tasks in one contest. The sequential structure can build the final solution by integrating knowledge from contestants with different skills, while the simultaneous structure maintains independence of contestants' solution search process. We conduct a controlled experiment to compare the two structures, and find that generally the sequential structure provides better contestant performance and contest outcomes.

**2 - Enhancing the "Call For Bids" to Improve Matching Efficiency in  
Online Labor Markets: Evidence from Freelancer.com**

Xue Guo, Temple University, Fox School of Business, 1801 North  
Broad Street, Philadelphia, PA, 19122, United States, Jing Gong,  
Paul A. Pavlou

To improve matching efficiency in online labor markets, we seek to enhance the "Call for Bids (CFB)" that helps service providers to understand the project requirements by reducing description uncertainty about the requested services. In this study, we first explore three dimensions of description uncertainty in the CFB: codifiability, flexibility, and outcome standards. Second, we examine the role of these dimensions in matching efficiency between the employer and service provider. Third, we explore the mediating role of bid characteristics (i.e., number of bids, average quality of bids, average price of bids) in the matching process. Theoretical and practical contributions are discussed.

**3 - How Much Monitoring is Optimal in Online Labor Markets –  
A Signaling Perspective**

Zhenhua Wu, PhD, Nanjing University, China

In this paper, we build a theoretical model to investigate the online labor market. We assume that: 1) There is an online monitoring system which could perfectly reveal online worker's effort level but imperfectly reveal productivity; 2) The online worker wants to signal his ability to market and build a reputation as a worker with high productivity, and the firm wants to maximize its profit by selecting an appropriate monitoring intensity. We show that the appearance of an online monitoring system could help the worker successfully signal his ability through the hourly wage or the effort level which cannot be obtained without the monitoring system. Furthermore, the intervening of the firm with a positive monitoring intensity could facilitate the worker to separate himself on the market. However, the monitoring system would distort the labor supply by achieving an effort level more than the case of complete information. Besides, we characterize separating equilibria where the high-productivity worker chooses lower hourly wage than the low-productivity one. We also find that there is a substitutional effect between the firm's monitoring intensity and the worker's effort level. Several policy and empirical implications are generated from our equilibrium predictions.

**4 - Role of Reference Points in the Goal-directed Platform:  
A Randomized Field Experiment**

Qinglai He, Arizona State University, Tempe, AZ, United States

Goal-directed platforms have seen tremendous development. Assisting users in effectively and efficiently attaining their goal is the key to both users' and goal-directed platforms' success. In this study, we focus on the role of reference points in individuals' goal pursuit in the goal-directed platforms. We propose that highlighting alternative reference points in the push notification has a positive effect on individuals' goal pursuit, and users' activeness moderates such effect. We collaborated with a leading education start-up to conduct a large-scale randomized field experiment. Based on our preliminary results, we discuss our findings and plans for future work.

**5 - Impact of Online Retail on Movement of Long Tail Products:  
An Empirical Study**

Samayita Guha, Temple University, PA, United States,  
Rakesh Reddy Mallipeddi, Subodha Kumar

Retailers have now started to pay attention to long tail products that individually have low demand but in aggregate can combine to create higher demand than few best-selling products. In this study, we propose an econometric model to examine the behavior of long-tail products using data from a large retailer.



## ■ MB68

West Bldg 105C

### Joint Session QSR/DM: Journal of Quality Technology Invited Session

Sponsored: Quality, Statistics and Reliability

Sponsored Session

Chair: Xiao Liu

Co-Chair: Bianca Maria Colosimo, Politecnico di Milano, Politecnico di Milano, Milan, I-20156, Italy

#### 1 - JQT Invited Session

Bianca Maria Colosimo, Politecnico di Milano, Via La Masa, 1, Milan, I-20156, Italy

In the JQT session three panelists are invited to present their research works, which have been recently published in JQT. A short discussion will follow to highlight the relevant features of manuscripts the journal is looking for.

#### 2 - 50 Years of the Journal of Quality Technology

Fugee Tsung, HKUST, Clearwater Bay Road, Hong Kong, Hong Kong

Abstract not available.

#### 3 - Multi-Scale Diagnosis of Spatial Point Interaction via Decomposition of the K Function-Based T2 Statistic

Qiang Zhou, University of Arizona, Tucson, AZ, United States

Abstract not available.

#### 4 - Two-level Augmented Definitive Screening Designs

Abby Nachtsheim, Pennsylvania State University, State College, PA, United States

Abstract not available.

## ■ MB69

West Bldg 106A

### Funding Opportunities for QSR

Sponsored: Quality, Statistics and Reliability

Sponsored Session

Chair: Yisha Xiang, Lamar University

#### 1 - Funding Opportunities for QSR

Yisha Xiang, Lamar University, 2626 Cherry Engineering Building, Beaumont, TX, United States

This panel will discuss funding opportunities that are relevant to the Quality, Statistics and Reliability community, with emphasis on the Operations Engineering, Cyber Manufacturing, and Humans, Disasters and the Built Environment programs in the Division of Civil, Mechanical & Manufacturing Innovation at NSF. An open discussion and Q&A will follow the presentations.

#### Panelists

Georgia-Ann Klutke, National Science Foundation, 4201 Wilson Boulevard, Arlington, VA, 22230, United States

Robin Dillon-Merrill, National Science Foundation, Alexandria, VA, United States

Irina Dolinskaya, National Science Foundation, 2415 Eisenhower Ave, Alexandria, VA, 22314, United States

## ■ MB70

West Bldg 106B

### Topics in Scheduling and Parallel Computing

Sponsored: Computing

Sponsored Session

Chair: Oleg Shylo, University of Tennessee, Knoxville, TN, 37996, United States

#### 1 - Supporting an Additional Dimension of Parallelism in PEBBL 2.0

Jonathan Eckstein, Rutgers University, New Brunswick, NJ, United States

We consider some large-scale optimization applications which require branch-and-bound algorithms, but the processing of even a single subproblem requires significant parallelism. This talk describes enhancements to the PEBBL parallel branch-and-bound class library designed to support such applications.

Applications using these enhancements may simultaneously exploit two different kinds of parallelism, one within subproblems and another across multiple subproblems. We also discuss other changes to PEBBL for the 2.0 release.

#### 2 - A Constraint Based Snowplow Optimization Framework

Joris Kinable, Eindhoven University of Technology, De Lismortel 62, Eindhoven, 5612 AR, Netherlands, Willem van Hoeve, Stephen F. Smith

Snow plow optimization is a complex process in which routes for a fleet of vehicles have to be determined, while adhering to vehicle operating restrictions, resource utilization and replenishment constraints. We present an optimization framework for a real-world snow plow optimization problem in Pittsburgh, USA. Feasible routes and schedules are calculated using heuristics and a Constraint Programming approach. Commercial GIS data is used as the underlying data source. Evaluations are performed against commercial snow plow optimization software. In addition, pilot tests with actual vehicles are being conducted.

#### 3 - Team of Teams: Optimal Communication Structures for Concurrent Solvers

Oleg Shylo, University of Tennessee, 523 John D. Tickle Engineering Building, 851 Neyland Drive, Knoxville, TN, 37996, United States, Andrii Berdnikov

The focus is on the teams of concurrent optimization solvers that can attain high levels of parallelism required by extreme-scale computing. To explore theoretical properties of communication and its impact on computational performance, we model communication between individual solvers by stochastic processes. These theoretical constructs enable efficient evaluation of communication topologies without empirical testing, and are used to define a class of scalable communication design problems.

#### 4 - A State-Space Decomposition Algorithm for the Integrated Last-Mile Transportation Problem

David Bergman, University of Connecticut, Storrs, CT, 02451, United States, Arvind U. Raghunathan, John Hooker, Thiago Serra, Shingo Kobori

In this talk we discuss a state-space decomposition algorithm for the integrated last-mile transportation problem, which consists of the joint scheduling of passengers in a mass transportation system and limited-capacity last-mile delivery vehicles. The algorithm results in orders-of-magnitude performance gains over previously introduced integer programming models.

## ■ MB71

West Bldg 106C

### Recent Advances in Non-convex Optimization

Sponsored: Computing

Sponsored Session

Chair: Andres Gomez, University of Pittsburgh, Pittsburgh, PA, 15217, United States

#### 1 - Cuts for Polynomial Optimization

Chen Chen, The Ohio State University, Columbus, OH, United States, Daniel Bienstock, Gonzalo Munoz

We introduce intersection cuts for polynomial optimization via maximal S-free sets (termed outer-product-free sets). Such cuts can be used to generate improved convex relaxations. We also discuss implementation of these cuts in MINLP branch-and-cut software.

#### 2 - Optimality-based Domain Reduction for Inequality-constrained NLP and MINLP Problems

Carlos Nohra, Carnegie Mellon University, Pittsburgh, PA, United States, Yi Zhang, Nikolaos Sahinidis, Gang Rong

We propose novel optimality conditions for general inequality-constrained NLP and MINLP problems, which fully exploit the monotonicity of objective and constraints. Three reduction algorithms are developed separately for unconstrained, one-constraint, and multi-constraint problems. Through forward and backward bound propagation of subgradients with respect to each decision variable, the reduction procedures are developed and integrated with the global solver BARON. Significant memory and CPU time reductions are observed for many problems.

#### 3 - Continuing Work on Polynomial Optimization

Daniel Bienstock, Columbia University, Dept of IEOR, 342 Mudd, New York, NY, 10027, United States

We present continuing work on polynomial optimization problems, including cuts and approximate discretization. If time permits we will include a discussion on diagnosing infeasibility.

#### 4 - A Center Cut Algorithm for Quickly Obtaining Feasible Solutions and Solving Convex Mixed Integer Nonlinear Programs

David E. Bernal, Carnegie Mellon University, 5000 Forbes Avenue, Doherty Hall office 3116, Pittsburgh, PA, 15213, United States, Jan P. Kronqvist, Andreas Lundell, Tapio Westerlund, Ignacio E. Grossmann

We present a center-cut algorithm for convex mixed-integer nonlinear programs that can be used as a primal heuristic or as a deterministic solution strategy. The trial solutions are chosen at the analytical center of the linear approximation of the nonlinear constraints subject to the original integrality constraints, with the idea that this trial solution is likely to be feasible. At this solution, the linear approximation is refined. The procedure is repeated iteratively, leading to convergence to a feasible solution. Proofs for the finite convergence of the algorithm are provided, and computational results show that the algorithm quickly finds feasible solutions to convex MINLPs.

## ■ MB72

West Bldg 211A

### Joint Session Wagner/Practice: Daniel H. Wagner Prize for Excellence in Operations Research Practice

Emerging Topic: Daniel H. Wagner Competition

Emerging Topic Session

Chair: Patricia Neri, SAS Institute, Inc., 104 Grandtree Ct., Cary, NC, 27519, United States

#### 1 - Primal-Dual Algorithms for Order Fulfillment at Urban Outfitters, Inc.

Vivek Farias, MIT, 100 Main Street, Cambridge, MA, 02142, United States, John M. Andrews, Aryan Khojandi, Chad Yan

We formulate the omni-channel fulfillment problem as an online optimization problem. We propose a novel algorithm for this problem based on the primal-dual schema. Our algorithm is robust: it does not require explicit demand forecasts. This is an important practical advantage in the apparel-retail setting where demand is volatile and unpredictable. We provide a performance analysis establishing that our algorithm admits optimal performance guarantees in the face of adversarial demand. We describe a large-scale implementation of our algorithm at Urban Outfitters, Inc. This implementation processes on average eighteen thousand customer orders a day, and as many as one hundred thousand orders on peak demand days. We estimate conservatively that the system has saved at least six million dollars annually relative to an incumbent industry standard fulfillment optimization implementation. This saving is achieved through optimal order-fulfillment decisions that simultaneously increase turn and lower shipping costs.

#### 2 - Centralized Admissions for Engineering Colleges in India

Yash Kanoria, Columbia Business School, 404 Uris Hall, New York, NY, 10027, United States, Surender Baswana, Partha Pratim Chakrabarti, Sharat Chandran, Utkarsh Patange

We designed and implemented a new joint seat allocation process for over 500 programs across 80 engineering colleges in India, including the Indian Institutes of Technology (IITs). Our Deferred Acceptance-based process overcomes a number of challenges. The joint seat allocation process has been successfully running since 2015, with a 70% reduction in vacancies at the IITs. Particular concerns have been (i) allocative efficiency and reducing vacancies due to students accepting a seat but then withdrawing or not reporting for classes, (ii) transparency, integrity and fairness, (iii) logistical simplicity for both candidates and institutes, and (iv) the incentive structure for candidates.

## ■ MB73

West Bldg 211B

### Innovations in Healthcare Delivery

Sponsored: Health Applications

Sponsored Session

Chair: Alex Mills, Kelley School of Business, Indiana University Bloomington, Bloomington, IN, 47405, United States

#### 1 - Healthcare Payment Model Impact on Hospital Readmissions

Jon M. Stauffer, Assistant Professor, Texas A&M University, 4217 TAMU, College Station, TX, 77843, United States, Jonathan Helm, Kurt M. Bretthauer

We examine how pay-for-performance (P4P) reimbursement plans, such as bundled payments and the Hospital Readmission Reduction Program (HRRP) impact the motivation for providers to reduce readmissions. Results show that P4P plans do motivate extra readmission reduction effort, but that misalignments can occur between the provider's efforts and the minimum total system cost effort. We also find there is only a small window when the bundled payment price is large enough to motivate all providers to reduce readmissions, but not so

large as to over-motivate a smaller provider to perform effort exceeding the minimum total system cost effort.

#### 2 - Managing Patient Panels with Nonphysician Providers

Hessam Bavafa, Wisconsin School of Business, 4284C Grainger Hall, 975 University Avenue, Madison, WI, 53706, United States, Sergei Savin, Christian Terwiesch

In recent years, the drive to contain health care costs has increased scrutiny of the traditional mode of delivering primary care where a patient is treated only by his primary care physician. In particular, greater reliance on non-physician providers has been suggested as a lower-cost alternative to the traditional set-up. We study the overall impact of non-physician providers on the physician's expected daily compensation and patients' expected health.

#### 3 - The Business of Healthcare: Physician Integration in Bundled Payments

Turgay Ayer, Georgia Institute of Technology, School of Industrial and Systems Engineering, Groseclose 417, Atlanta, GA, 30332, United States, Jan Vlachy, Mehmet U.S. Ayvaci

Under the prevailing fee-for-service payments, incentives of hospitals and physicians are misaligned, leading to large inefficiencies. Bundled payments unify payments to the hospital and physicians and are expected to encourage care coordination and reduce costs. However, as hospitals differ in their relationships with physicians in influencing care level of physician integration, it remains unclear what spectrum of physician integration will facilitate bundling. We study (1) the impact of the level of integration between the hospital and physicians in the uptake of bundled payments, (2) the consequences of bundling with respect to overall care quality and costs/savings.

#### 4 - Estimated Time to Discharge Building the ETA for Hospitals

Jean Pauphilet, MIT, Cambridge, MA, 02139, United States, Dimitris Bertsimas

Number of beds, whose availability is driven by patient discharges, is one of the most critical resources in any hospital. As a result, accurate prediction of time-to-discharge could significantly improve daily operations. In this work, we combine advanced machine learning methods with expertise and insights from medical staff, social workers and operations to compute personalized Time-to-Discharge estimates for each individual inpatient. To that end, we also build a predictive model to anticipate discharge destination as well. Joint work with BIDMC, Boston, MA.

## ■ MB74

West Bldg 212A

### Exact Approaches and Approximations in Multiobjective Optimization

Sponsored: Multiple Criteria Decision Making

Sponsored Session

Chair: Serpil Sayin, Koc University, Istanbul, 34450, Turkey

#### 1 - An Algorithm for Solving Bi-objective Integer Programming Problems

Ozlem Karsu, Bilkent University, Bilkent University, Ankara, 06800, Turkey, Firdevs Ulus, Saliha Dogan

We propose an objective-space based algorithm to solve bi-objective integer programming problems, where we assume that the set of all nondominated points are included within a bounded set. In each iteration of the algorithm a single Benson-type (weighted Chebyshev) scalarization is solved. The computational experiments demonstrate the satisfactory performance of the algorithm.

#### 2 - Tractability of Convex Vector Optimization Problems in the Sense of Polyhedral Approximations

Firdevs Ulus, Bilkent University, Industrial Engineering Department, Bilkent, Ankara, 06800, Turkey

A recent solution concept for convex vector optimization problems (CVOPs) which is motivated from a set optimization point of view consists of finitely many efficient solutions that generate polyhedral inner and outer approximations to the Pareto frontier. A CVOP with compact feasible region is known to be bounded and there exists a solution of this sense to it. However, it is not known if it is possible to generate polyhedral inner and outer approximations to the Pareto frontier of a CVOP if the feasible region is not compact. This study shows that not all CVOPs are tractable in that sense and gives a characterization of tractable problems in terms of the well known weighted sum scalarization problems.

### 3 - Experiments with Two Relaxations for Multiobjective Integer Linear Programs

Serpil Sayin, Koc University, College of Admin Sciences and Economics, Rumeli Feneri Yolu Sariyer, Istanbul, 34450, Turkey

We study two relaxations of multiobjective integer linear programs. The first one is the result of an LP relaxation of the feasible set. This leads to a formulation that can be solved as a multiobjective linear programming (MOLP) problem. The second one is a convex hull relaxation of the problem in the outcome space. This relaxation makes it possible to relate extreme supported nondominated solutions of the original problem and the nondominated set of the relaxed problem. We then conduct some preliminary experiments to evaluate the information delivered by the relaxations for some different problem types.

### 4 - MSEA 2.0: A Multi-stage Exact Algorithm for Multi-objective Pure Integer Linear Programming in Julia

Aritra Pal, Sr Operations Research Specialist, BNSF Railway Company, 6301 Sabbatical Street, Apt 938, Fort Worth, TX, 76131, United States, Hadi Charkhgard

We present a new exact method for multi-objective pure integer linear programming, the so-called Multi-Stage Exact Algorithm (MSEA). The method combines several existing exact and approximate algorithms in the literature, either to compute the entire efficient set or to compute the minimum of a linear function over the entire efficient set of any multi-objective pure integer linear program. The proposed method supports execution on multiple processors and is available as an open source Julia package (MSEA.jl), in GitHub. Another desirable feature of the package is that users can easily customize the package to develop their own custom-built exact solvers for their specific problems.

## ■ MB75

West Bldg 212B

### Quantitative Methods Supporting Operational Decisions

Sponsored: Military and Security

Sponsored Session

Chair: William Caballero, Air Force Institute of Technology, WPAFB, OH, 45424, United States

#### 1 - Drone-aided Border Surveillance with an Electrification Line Battery Charging System

Seon Jin Kim, University of Houston, 422 Cypress Vista, Houston, TX, 77094, United States, Gino J. Lim

Mobile and fixed border surveillance systems are often used to enhance the comprehensive situational awareness along the U.S. border lines. Drawbacks of such systems include limited operating capability, blind spots, and physical fatigue of field agents. The use of drones is an ideal way to overcome these issues in border patrol activities. Therefore, we present a drone-aided border surveillance system with E-line battery charging systems to wirelessly charge drones during the flight to extend flight duration. For operational purposes, an optimization model and solution algorithm to schedule drone flights for the proposed system.

#### 2 - A Multi-objective Trilevel Optimization Model for Integrated Air Defense System Penetration

Brian J. Lunday, Air Force Institute of Technology, 2950 Hobson Way, Department of Operational Sciences, WPAFB, OH, 45433, United States, Aaron M. Lessin, Raymond R. Hill

We present a trilevel math programming formulation in which an intruder identifies subsets of a defender's air defense batteries to respectively destroy and degrade, subject to budget constraints; a defender subsequently adjusts their array of defensive assets subject to certain time and movement limitations; and the intruder selects a penetration path. Within this framework, the intruder and defender respectively seek to minimize and maximize the expected exposure time of the intruding aircraft to engagements. We present a reformulation to a bilevel program, customized heuristics, and the results of heuristic performance on synthetic-but-representative scenarios.

#### 3 - Approximate Dynamic Programming for Military Medical Evacuation Dispatching Policies

Phillip Rolland Jenkins, Air Force Institute of Technology, WPAFB, OH, 45424, United States, Matthew J.D. Robbins, Brian J. Lunday

Military medical planners must consider how aeromedical evacuation (MEDEVAC) assets will be dispatched prior to engaging in combat operations. We formulate a Markov decision process model to examine the MEDEVAC dispatching problem. We develop and test two distinct approximate dynamic programming (ADP) solution techniques. The first technique utilizes least-squares temporal differences (LSTD) learning, whereas the second technique leverages neural network (NN) learning. A notional planning scenario is examined to determine the efficacy of our ADP solution techniques. Results indicate that the NN policies substantially outperform both the LSTD and currently practiced policies.

### 4 - Solving the Heterogeneous Multi-stage Weapon Target Assignment Problem with Adaptive Dynamic Programming

Darryl K. Ahner, United States Army, 135 Eastwick Court, Dayton, OH, 45440-3647, United States, Alexander Gill Kline, Carl R. Parson

The weapon target assignment (WTA) problem seeks, within an air defense context, to assign interceptors (weapons) to incoming missiles (targets) to maximize the probability of destroying the missiles. In the Dynamic WTA (DWTA), there is knowledge of targets that pose an immediate threat and it is known, to a probability distribution, how many and what type of targets will follow in a subsequent stage. This paper develops a real-time, near optimal solution technique for the heterogeneous DWTA which utilizes the CAVE Algorithm. Further, it compares the results to an optimal Markov Decision Process for smaller problem instances and a baseline policy for larger problem instances.

## ■ MB76

West Bldg 212C

### Data-driven Approaches for Smart Manufacturing System Analysis, Monitoring, and Control

Emerging Topic: Design and Control of Manufacturing Systems

Emerging Topic Session

Chair: Xiaoning Jin, Northeastern University, Boston, MA, 02115, United States

Co-Chair: Weihong Guo, Rutgers, The State University of New Jersey, Rutgers, Piscataway, NJ, 08854, United States

#### 1 - Process Variation Modeling and Monitoring for Interconnected Additive Manufacturing using Cloud Data

Hui Wang, PhD, Florida State University, FL, United States, Jie Ren, Arriana Nwodu, Tarik Dickens

Additive manufacturing (AM) has its flexibility of creating a high variety of products with complex structures. However, due to frequent changes in production demands, AM processes usually do not have sufficient data to establish a baseline for effective quality monitoring and process control. This talk envisions a solution by using an inter-connected AM environment based on cloud platforms, by which production data from multiple AM processes can be shared and exchanged with each other to jointly learn AM process variations. A case study demonstrates that the proposed algorithm.

#### 2 - NARNET-based Degradation Analysis under Time-Varying Operating Conditions

Xiaoning Jin, PhD, Northeastern University, Boston, MA, United States, Anqi He

We present a new prognostic modeling method based on nonlinear autoregressive neural network (NARNET) for computing remaining useful life (RUL) of degraded systems under dynamic operating conditions. Our approach consists of two processes: (1) an offline training process for modeling the degradation and failure zones using run-to-failure sensor measurements; (2) an online remaining useful life (RUL) prediction algorithm. The operating conditions are forecasted by a NARNET model based on the unit's operating history. We show that the prognostic model provides more accurate RUL prediction, demonstrated with an aircraft turbine engine degradation dataset.

#### 3 - Image Analytics for Prognostics and Health Monitoring in Advanced Manufacturing System

Shenghan Guo, Rutgers, The State University of New Jersey, Piscataway, NJ, United States, Weihong Guo

Automatic sensing devices and computer systems have been widely adopted by the automotive manufacturing industry, which is able to record machine status and process parameters nonstop. The objective of this study is to explore and exploit the large amounts of recorded data to facilitate system prognostics and health monitoring. The proposed method represents machine status sequences in moving-window images and then extracts features using texture analysis. Classification results show that the proposed method can effectively distinguish between normal and abnormal processes. A case study on a critical asset from an automotive manufacturing plant is provided.



## ■ MB77

West Bldg 213A

**Disaster Preparedness, Response, and Recovery**

Sponsored: Public Sector OR

Sponsored Session

Chair: Pinar Keskinocak, Georgia Institute of Technology, Georgia Institute of Technology, Atlanta, GA, 30332, United States

Co-Chair: Seyma Guven Kocak, Georgia Institute of Technology, Atlanta, GA

**1 - Inequity-averse Shelter Location for Disaster Preparedness**

Sibel Salman, Koc University, Rumeli Feneri Yolu, Istanbul, 34450, Turkey, Mahdi Mostajabdaveh, Walter J. Gutjahr

We address selecting capacitated shelter locations in preparation for disasters under demand uncertainty and random transportation network disruptions by an inequity-averse approach. We develop a 2-stage stochastic programming model to minimize a linear combination of efficiency and inequity measures. Moreover, a service level is imposed by a chance constraint. We develop a tailored genetic algorithm (GA) to solve this problem for large real-life and benchmark instances. Our computational results show that the GA outperforms Cplex in terms of run time and solution quality. We derive insights from a case involving an earthquake-prone district of Istanbul.

**2 - The Post-disaster Debris Clearance Problem with Resource Allocation and Learning**

Seyma Guven-Kocak, Georgia Institute of Technology, 5211 Denmeade Dr, Atlanta, GA, 30345, United States, Pinar Keskinocak

In the aftermath of a disaster, debris needs to be cleared quickly and efficiently in order to continue critical response operations. Motivated by the debris clearance operations, this work addresses a problem of establishing connectivity on a disrupted network with inherent uncertainty and learning. Since the information on the clearance times of the roads only becomes available after the network is explored, this problem possesses exploitation / exploration trade-off. Considering learning and exploration / exploitation trade-off, we develop various exact and approximate solution methods in order to optimize the benefit accrued over time by connecting critical points in the network.

**3 - Time Synchronization Issues in Emergency Response**

Jordan Srour, Assistant Professor of Operations Management, Lebanese American University, Adnan Kassar School of Business, P.O. Box 13-5053, Beirut, 1102 2801, Lebanon

In any city - smart or not - emergency response is a critical service. In smart cities, the use of technology to manage access to and dispatching of emergency vehicles is particularly important. However, when a system must manage processes spanning multiple computers, clock drift becomes a prominent issue. In a case study with an existing emergency response provider, we show how analytics can be used to determine the impact and source of clock drift. We also show the impact that system design techniques can have in remedying this issue.

**4 - A Stochastic Integer Programming Framework for Large Scale Patient Evacuation under a Forecasted Disaster**

Kyoung Eric Kim, University of Texas-Austin, Austin, TX, United States, Erhan Kutanoglu, John Hasenbein

A major humanitarian challenge of a forecasted disaster such as a hurricane is to decide whether or not the patients in hospitals and nursing homes in the affected area should be evacuated. We propose a comprehensive modeling and methodological framework for large scale patient evacuation when an area is faced with such a disaster. We integrate a scenario generation scheme that uses updated hurricane forecasts and a scenario-based stochastic integer program to make decisions on resource allocation (for staging area locations, ambulances/ambuses, and sending and receiving staff) and patient movements. Real-world data from Southeast Texas region is used in our computational study.

**5 - Scheduling Staff for the FEMA National Response Coordination Center**

Erica L. Gralla, George Washington University, 800 22nd st NW, Rm 2680, Washington, DC, 20052, United States, Kai Friessecke, Shelby Grumer, Jillian D'Arrigo, Hernan Abeledo, Joseph Barbera

The Federal Emergency Management Agency's National Response Coordination Center coordinates federal support for response to major disasters. Producing staff schedules for the center is a challenge, since most staff have other commitments, and each position requires specific qualifications. We describe a scheduling approach that efficiently rosters qualified personnel and minimizes the violation of staff preferences, including days off, manager preferences, and others. Results show which preferences are hard to satisfy and provide recommended roster sizes and cross-training requirements.

## ■ MB78

West Bldg 213B

**Joint Session SOLA/PSOR/Practice Curated: Public Sector Location Applications**

Sponsored: Location Analysis

Sponsored Session

Chair: Rajan Batta, University at Buffalo (SUNY), Buffalo, NY, 14260, United States

**1 - Prepositioning of Supplies in Domain of Natural Disasters****Logistics: A Systematic Review of Operations Research and Management Science Papers**

Monir Sabbaghtorkan, University at Buffalo (SUNY), Amherst, NH, United States, Rajan Batta, Qing He

Prepositioning of supplies is an efficient way to improve the post-disaster relief efforts. In this paper, we explore and review OR/MS papers related to this topic to find the gaps and give directions to future researchers in this area. The classifications that are used in this paper are as follow. Authors affiliation, journals contribution, number of papers over the years and type of disaster considered by papers. Moreover, we would present the mathematical model features for each paper, like objective function, decision variables, constraints, solution methodology and etc.

**2 - Responding to Medical and Fire Emergencies on a Disrupted Network**

Gina Galindo, Universidad del Norte, KM5 Antigua via a Puerto Colombia, Puerto Colombia, Colombia, Juliette Garc a

Events such as heavy rains or extreme snowfall may disrupt roads and affect the response times of critical services such as fire and medical emergencies. This research develops a methodology for effectively allocating medical and fire emergencies to available facilities on a disrupted network. The methodology was applied to a case study in Barranquilla, Colombia. Based on the results, we recommend potential site for locating additional fire and medical facilities.

**3 - A Stochastic Programming Model for Emergency Supply Planning Considering Traffic Congestion**

Xiaofeng Nie, Texas A&M University, College Station, TX, United States, Qingyi Wang

Traffic congestion delays emergency supply after disasters, but it is seldom considered in the emergency logistics literature. To fill this gap, we propose a traffic congestion incorporated two-stage stochastic programming model that facilitates the planning of supplies pre-positioning and post-disaster transportation. The corresponding mixed-integer nonlinear program is efficiently solved with a generalized Benders decomposition algorithm. A case study on a hurricane threat in the southeastern U.S. shows the superiority of our model and provides managerial insights.

**4 - A Bi-Level Combined Facility Location and Network Design Problem in Hazardous Materials Transportation**

Xufei Liu, University of South Florida, Tampa, FL, United States, Changhyun Kwon

In this paper, we consider a bi-level optimization problem for hazardous materials transportation to determine facility locations and network design. The leader intends to minimize the total cost of facility costs and exposure risk by restricting the shipment and anticipates the reaction of the followers who want to minimize the transportation costs by choosing the shortest path for shipments. Considering the uncertainty of the number of trucks and exposure risk, we formulate a robust bi-level combined facility location-network design model and propose a cutting plane algorithm.

**Monday, 12:30PM - 2:30PM****Monday Poster Session**

Exhibit Hall Poster

**Monday Poster Session**

Poster Session

Chair: Neng Fan, University of Arizona, 1127 E. James E. Rogers Way, P. O. Box 210020, Tucson, AZ, 85721, United States

Co-Chair: Junming Yin, University of Arizona, Management Information Systems Department, McClelland Hall, Room 430BB, Tucson, AZ, 85721, United States

Co-Chair: Burcu B. Keskin, University of Alabama, 4138 Meretta Lane, Tuscaloosa, AL, 35406, United States

**1 - Comparative Analysis of the Machine Learning and Statistical Classifiers**

Ivan Belik, Assistant Professor, Norwegian School of Economics, Helleveien 30, Bergen, 5045, Norway

Since machine learning - statistics gap has experienced an outstanding reduction in the last years, machine learning methods have been applied for classification purposes as an alternative to purely statistical methods. In the given research we analyze machine learning and statistical techniques for the classification purposes and compare the efficiency and classification accuracy of those techniques. Specifically, we build the Na ve Bayes Classifier, based on the Bayesian Statistics concept, and the Artificial Neural Network classifier, based on the functional aspects of the biological neural networks. We are running the given competing paradigms over the variety of real-world datasets.

**2 - Dynamic Cloud Resource Optimization of B2C E-commerce Process Using Deep Reinforcement Learning**

Ming Gao, Associate Professor, Dongbei University of Finance & Economics, China, Jianshan Street 217, Shahekou District, Dalian, 116030, China

Current research on the optimization of cloud resources deployment for e-commerce platform is less based on the business process level and real world scenarios. In order to dynamically optimize the cloud resources for specific service scenarios of e-commerce transaction process, this paper analyzes the characteristics of the B2C e-commerce transaction scenario from published real world transaction history data, and apply the deep reinforcement learning algorithm to generate cloud resource realtime optimization strategies. Our work provides a reference solution for e-commerce companies to bridge the gap between business process goals and cloud resources efficiency.

**3 - Recent Approaches to Creating and Analyzing Big Data in Technology Management and Commercialization**

Clovia Hamilton, Assistant Professor of Management, Winthrop University, 701 Oakland Avenue, 310 Thurmond Building, Rock Hill, SC, 29733, United States

This is a study of three (3) technological advances related to Big Data: web scraping, natural language processing and machine learning. This research identifies ways in which these advances can become more relevant and useful to empirical researchers in the field of technology and innovation management. This research provides a brief look at some applications of these advances in research studies, and engenders a broader discussion around the relevance and impact of these advances to research in technology and innovation management. In particular, making use of these advances in empirical research related to technology commercialization was researched and is discussed.

**4 - Benchmarking Stream Processing Frameworks**

Giselle van Dongen, Ghent University, Ghent, Belgium, Dirk Van den Poel

Due to the increasing interest in real-time processing, many stream processing frameworks were developed. However, no clear guidelines have been established for choosing a framework and designing efficient processing pipelines. We fill this gap by establishing a benchmark methodology for fine-grained benchmarking of common operations on multiple metrics: latency, peak throughput, sustainable throughput, memory usage and cpu utilization. We implemented this benchmark for four popular stream processing frameworks: Spark, Storm, Flink and Kafka Streams.

**5 - A Two-stage SMAA-DEA Model for Supply Chain Evaluation and Rank**

Sheng Ang, University of Science and Technology of China, 96 Jinzhai Road, Hefei, China, Yunxia Zhu, Feng Yang

We integrate stochastic multi-criteria acceptability analysis technique (SMAA) and data envelopment analysis (DEA) methodology and propose a two-stage SMAA-DEA model for supply chain rank and efficiency evaluation with stochastic criteria values. Our study extends network DEA to address uncertain or stochastic measures. The developed model can be considered as an MCDM method with a two-stage additive DEA value function. An empirical study of 27 supply chains evaluation is presented to illustrate the proposed models.

**6 - Multivariate Stochastic Approximation versus Design of Experiments for Learning Vector Quantization Hyperparameter Tuning**

Trevor Bihl, Air Force Research Laboratory, 209 George Wythe Way, Beavercreek, OH, 45434, United States, Daniel Steeneck

The Generalized Relevance Learning Vector Quantization-Improved (GRLVQI), a Kohonen neural network classifier, is very accurate in the identification of communication devices in robust security applications. However, GRLVQI, like neural networks in general, has multiple hyperparameters which have been tuned via ad hoc and experiential methods. Herein, the authors consider two approaches to finding optimal GRLVQI hyperparameters: 1) factorial experimental design and 2) stochastic approximation. The results show that stochastic approximation has an improvement in accuracy over factorial designs while not constraining the design space.

**7 - Machine Learning to Establish Confidence in Project Due Date Setting**

Yu Xia, Associate Professor, College of William and Mary, Mason School of Business, 101 Ukrop Way, Williamsburg, VA, 23185, United States, Jie Ding

Erroneous setting of project due date can cause huge waste of resources. In project management, various postulated models are used to forecast project due date. However, project due date is influenced by many supply chain factors and some unexpected events. It is difficult to decide whether a postulated model is well-specified or not since they usually involve complex settings with nontrivial likelihood functions or vague priors on their parameters. In this paper, we works on establishing a quantitative index for confidence level of a due date setting. We also gather results from multiple models and come up with a self-learning self-adjusting final result to tackle the task.

**8 - Atmospheric Monitoring Using Nano-satellites**

Jean-Pierre Ibitokun, Graduate Student, University of Arkansas at Little Rock, EIT South University Avenue, Little Rock, AR, 72204, United States, Yupo Chan, Edmond Wilson, Po-Hao Adam Huang

Global warming concerns have led to environmental monitoring of our planet. The GOES satellite, a multi-billion platform, has been a key player in atmospheric sensing and weather forecast. We propose to use a constellation of CubeSat's, or nano-satellites, to perform a similar function at a much lower cost. Signals from an onboard spectrometer will map atmospheric water vapor concentrations, CO<sub>2</sub>, oxides of nitrogen, hydroxyl radicals and ozone concentrations, and recording solar spectra to establish trends between solar flux and atmospheric water vapor concentrations. This is to be validated against the patterns discerned from the GOES data using signal and image processing.

**9 - Transforming Organizations Through the Use of Metadata**

Christy W. Goodnight, University of South Alabama, Mobile, AL, United States

This poster examines the effect of the organizational structure of data of all types on a new process called the metadata transformational process. Adding a layer of metadata to all the data collected within our organization allows for us to use this knowledge in new and innovative ways that has the potential to transform the way we not only do business, but also the way our society functions. Thus, organizations that go through a metadata transformation will enable knowledge sharing which has the potential to facilitate innovation across the globe.

**10 - Estimating Youden Index Under the Multivariate ROC Curve in the Presence of Missing Mass Malignant and Benign Biomarker Data**

Lakmali Weerasena, University of Tennessee Chattanooga, 615 McCallie Ave, Chattanooga, TN, 37403, United States

Multivariate Youden index (J) and its corresponding optimal cut-point (c\*) have become the most effective and efficient approach in multi-biomarker mass data analysis to distinguish diseased from the healthy in this digitized era. However, the existing statistical classical approach does not produce exact solutions in the presence of nuisance parameters and missing and group mass data. This proposed novel high-performing computational-based generalized Variable Method is an alternative procedure to produce exact statistical inferential results for J and c\* in the presence of such constraints.

**11 - Vehicle Flow Control Using Reinforcement Learning on Manufacturing Environment**

Younkook Kang, Seoul National University, Seoul, Korea, Republic of, Sungzoon Cho

Automated Material Handling System (AMHS) which is responsible for movements between equipment is becoming an important factor of manufacturing competitiveness in semiconductor industry environment. In order to control traffic, traffic congestion should be reflected as a cost but it is hard to find proper cost. Our study focuses on setting traffic cost to maximize throughput at a key area. We suggest a method to adjust routing cost using reinforcement learning. It can help adapting traffic pattern changes without human interference. In the end, it can contribute improving manufacturing productivity.

**12 - Sequencing and Line Balance Interaction in Multi-worker Mixed-model Assembly Lines**

Mary Beth Kurz, Clemson University, 110 Freeman Hall, Clemson, SC, 29634-0920, United States

Mixed-model assembly requires line balancing and sequencing. The line balance and sequence may induce work overload. Given a fixed line balance, a sequence can be adjusted to minimize work overload: a skip policy allows a utility worker to take over a workpiece that will cause overload while the normal worker works on the next workpiece and swimming allows a worker to move into adjacent stations. Large products are assembled at stations with one or more workers per station. We address sequencing with skips and swims in a multi-worker mixed-model assembly line.

**13 - A Cellular Manufacturing Implementation in Microwave Manufacturing**

Okan Karatay, Production Manager, Aselsan, Konya Yolu 8. Km, Ogulbey Mah. 3051. Sok. No:3, Ankara, 06830, Turkey, Yuce Cinar Baysal

Nowadays, one of the effective ways of dealing with manufacturing drawbacks in a high mix low volume environment is the CM. In this study, we first propose a manufacturing cell that is designed to replace the traditional job shop layout of the Microwave manufacturing company. Secondly, we focus on the scheduling that creates the continuous flow and provides the line balance. Moreover, we mention the human aspect of this implementation which is as critical as technical ones. Thirdly, we evaluate the performance of the CM with the conventional production layout by using the company's KPI. After analyzing the outcomes of the implementation, the benefits associated with cellular manufacturing are listed.

**14 - A Bayesian Stochastic Frontier Model for Productivity Index**

Jessie Nouri, UWM, Milwaukee, WI, United States

Stochastic Frontier Model (SFM) is a linear regression with covariates and a random effect term which captures variation of production across various firms. This research develops a semi-parametric Bayesian SFM for predicting the productivity index across production lines of a major firm. The distribution of efficiencies is modelled through a Dirichlet process prior.

**15 - The Relation of Product Variety and Structure to Subassembly Inventory**

Jeonghan Ko, Ajou University; University of Michigan, Ann Arbor, MI, 48109, United States, Kunju Kim

This research elaborates the relationship between product variety and the safety inventory of subassemblies thorough multi-stage assembly. We identifies the optimal locations to hold subassemblies along the assembly steps to minimize the total subassembly inventory levels on the condition of little component commonality. In particular, we show that different product structure will lead to different levels and optimal locations for subassembly inventory.

**15B - Real-time Health Monitoring of Wiring Systems for Smart Manufacturing**

Daeil Kwon, Professor, UNIST, Ulsan, 44919, Korea, Republic of, Jinwoo Lee, Namhun Kim

In manufacturing facilities, wiring systems transmit and receive signals to communicate between modules and systems. Stress conditions may degrade the performance of wiring systems, causing intermittent faults, interlocking, and eventually facility downtime. Timely maintenance of wiring systems is required to ensure the reliability and availability of manufacturing facilities. This presentation discusses a non-destructive method to allow for condition-based maintenance of wiring systems. Experimental results demonstrate the proposed method can serve as a real-time health indicator of wiring systems, and can be used for proactive maintenance planning toward near zero downtime.

**16 - What Effects do Owner-operator Incur as a Result of Negotiating Behavior for Freight Transportation**

Shervin Espahbod, Wilfrid Laurier University, Waterloo, ON, Canada

The main approach to be a self-employed in trucking industry is to purchase or lease a truck as an independent trucker. The self-employed driver can receive direct orders or subcontract for a transportation firm. Although there is a substantial potential profit for self-employed carriers, the trucking industry is an extremely competitive and uncertain market. The person with the lowest amount of bid, is the winner of the spot market auction. By cutting their profits and putting lowest bids, self-employed drivers win bids from far distance, while closer corporate truckers are unable to win the bid. This study will examine the results of the inefficiency from this behavior.

**17 - Do Attractive People Make a Better Deal Investigation of Social Factors in Supply Chain Management**

Lyudmyla Starostyuk, PhD Candidate, The University of Texas at Arlington, 701 S. West Street, Arlington, TX, 76019, United States, Chen Kay-Yut, Prater Edmund L

Although it is well known that people form impressions of others based on their appearance, little is known about the role of facial character judgments in contracting. We study the role of social factors such as trustworthiness, attractiveness, and dominance in better pricing in a supply chain contract game. The experimental study shows that the female supplier who is confident in her attractiveness sells products to the male buyer for the higher average price while the male supplier does the opposite. The trustworthy looking female receives more expensive offers from the male supplier but sells products cheaper to the female buyer as well as the dominant female does.

**18 - The Importance of Referent Power in Team Mental Models**

Shihao Ge, Research Assistant, University of Washington Bothell, 18115 Campus Way NE, Bothell, WA, 98011, United States, Deanna Kennedy

Being on the same page by forming team mental models is important for project success. This takes communication, however, the communicator may help or hinder the development of team mental models. Herein, we look at how relationships and behaviors of the communicator on other team members and how that may impact mental model formation.

**19 - Predicting Hurricane Landfall from the Atlantic on United States Territories Using Historical Advisory Data**

Obe J. Joseph, SUNY University at Buffalo, Buffalo, NY, United States

The objective of this study is to create a landing deviation model. The study involves collecting and tabulating advisory text data from 1998 to 2017, from the National Hurricane Center. It analyzes the distribution of the distance deviation between the forecasted landfall and the true landing, given the number of hours before landfall.

**20 - Natural Disaster Damage Loss Prediction Using Social Media Data: The Study Case of Hurricane Irma**

Ling Lin, University of Buffalo, 319 Kaymar Dr, Buffalo, NY, 14228, United States, Qing He, Rajan Batta

Our research presents an aggregated disaster loss prediction model by examining Hurricane Irma's Tweet data and users' demographic information through implementing sentiment and linear regression analyses. Sentiment scores were utilized as new input variables along with other factors in regression model to predict various types of disaster damage losses. The results show the potential power of social media data in predicting both the number of damaged units and the damage loss in dollars.

**21 - Optimization of Information Coverage Using Social Media During Natural Disasters**

Bairong Wang, PhD, University at Buffalo (SUNY), Buffalo, NY, 14226, United States, Rajan Batta

One of the challenging problems for social media crisis sensing is collecting enough useful data from social media. This study aims at designing and optimizing an information coverage strategy within local areas when a disaster event occurs. A bi-level information coverage model is designed to model the situations where information is collected from different local areas for crisis sensing. This model includes an upper-level model that optimizes the resources allocating among different local areas and a correspondingly lower-level model that optimizes the positioning of computing resources to maximize the weighted coverage. Test results of the model prove a sound performance of the model.

**22 - Using Real-time Operational Data to Increase Labor Productivity in Retail**

Pablo Jofr, Universidad de Chile, Beaucheff 851, Santiago, 8370456, Chile, Marcelo Olivares, Andres I. Musalem

This research is focused on developing models to support dynamic systems that can reassign labor to different activities. This work utilizes data from a pilot study in a store of a home improvement retail chain in the U.S. Security cameras were used to track the number of customers and employees on different sections. We use these operational data to measure - in real time - the demand for services in a specific store department, and the service capacity. This information can be linked to point of sales data, to measure the effect of the number of employees on the sales of specific departments. All this provide information for a dynamic labor allocation system in order to prioritize where to allocate employees.

**23 - Strategies with Incomplete Information for Interactions Between Sectors in Concession Period Length of a PPP Project**

Zhouyang Lyu, Hohai University, Nanjing, 211100, China

This work studies the intention of private sector investment under tenuous rules of law (Incomplete Information) and associated with concession period length. First, a static game model was created to analyze the tactical concession length, indicating 60% of the legal maximum length. Then, to analyze private investment promotion, another model was created to investigate the influences of the investment ratio. Results from the models show: 1) "zero concession is negated; 2) only under extreme risk the private sector's motivation will be influenced, but with limitation.



#### 24 - Difference-of-convex (DC) Functions offer a Unified Framework for High-dimensional Sparse Estimation

Shanshan Cao, PHD Student, Georgia Institute of Technology,  
500 Tech Parkway, Atlanta, GA, 303320435, United States,  
Xiaoming Huo

Under the linear regression framework, we study the variable selection problem when the underlying parameter is sparse. With difference-of-convex (DC) penalties, which includes most existing non-convex penalties, such as SCAD, MCP, etc, we consider the directional-stationary solutions. We show that under mild conditions, a certain subset of d-stationary solutions have the ideal statistical properties: asymptotic estimation consistency, model selection consistency, and efficiency. This work shows that DC is a nice framework to offer a unified approach to the existing works when non-convex penalty is involved. Our theoretical results bridge the communities of optimization and statistics.

#### 25 - Decentralized Mixed Integer Programming Theory and Application Innetworked Microgrids Planning

Masoud Barati, University of Pittsburgh, Benedum Hall  
3700 O'Hara Street, Pittsburgh, PA, 15261, United States

A method for formulating and solving a networked microgrid planning problem is performed. Several forces are motivating the development of decentralized microgrid operations, including growing interest in decentralized control frameworks. The method extends the alternating direction method of multipliers (ADMM) along with several refinements to mitigate traps in local optimality that result from the nonconvexity of networked microgrid planning. The scalability observed so far suggests that this method is a practical option for use with large networks and may provide a significant benefit for computational speed.

#### 26 - Learning the Best Metaheuristic Parameters Set for Car-passenger Matching Problem in on Demand Mobility Services

Arslan Ali Syed, Bavarian Motor Works, Schroefelhofstr 12,  
Muenchen, 81375, Germany, Klaus Bogenberger

Metaheuristics provide good suboptimal solution to an optimization problem in a reasonable time, but extensive effort is required to select a good set of parameters to obtain reasonable performance. In this work we propose that a neural network could be trained that takes specific features of the problem instance and outputs the best parameters for a specific metaheuristic algorithm. We extract various features for car-passenger matching problem to train a neural network that depending on problem instance returns the best metaheuristic parameters set.

#### 27 - Dynamic Car-passenger Matching Based on Tabu Search Metaheuristics

Marvin Erdmann, PhD, BMW, Munich, Germany

On Demand Mobility is a concept that would lead to an enhanced use of shared mobility services. To avoid a decline of convenience for the costumers my work's focus is the realization of a Metaheuristic which matches requests and vehicles in order to find a near-to-optimal solution for the system.

#### 28 - A Variable Neighbourhood Descent Heuristic for Conformational Search Using a Quantum Annealer

Brad Woods, 1QBit, 4436 Nanaimo St., Vancouver, BC, V5N5J3,  
Canada, Dominic Marchand, Moslem Noori, Gili Rosenberg,  
Austin Roberts

Discovering the low-energy conformations of a molecule is of great interest to computational chemists with potential applications in ab-initio materials design and drug discovery. In this paper, we propose a variable neighbourhood search heuristic for the conformational search problem. Using the structure of the molecule, neighbourhoods are chosen to allow for efficient optimization, and also allowing the application of a quantum annealer for this step of the iteration. The proposed method can adapt to the size and topology of the available quantum annealer chip through careful definition of neighbourhoods, making it scalable with respect to future hardware specifications.

#### 29 - M-estimator for Robust Regression Revisited: Robustness and Tractability Tradeoffs

Ruizhi Zhang, Georgia Institute of Technology, Georgia Institute of Technology, Atlanta, GA, United States

We investigate two important properties of M-estimator, robustness and tractability, in linear regression when the data are contaminated by outliers. Specifically, robustness means the statistical property that the estimator should always be close to the true parameters regardless of the distribution of the outliers, whereas tractability means the computational property that the estimator can be computed efficiently even though the objective function of the M-estimator can be non-convex. By learning the landscape of the empirical risk, we show under mild conditions, many M-estimators enjoy robustness and tractability properties simultaneously when the percentage of outliers is small.

#### 30 - High Dimensional Global Optimization via Optimization of Communicating Low Dimensional Complimentary Subspaces

Logan Michael Mathesen, Arizona State University, 699 S. Mill Ave, Tempe, AZ, 85281, United States, Giulia Pedrielli

Global optimization suffers the curse of dimensionality. High dimensional search is dominated by the assumption of low effective dimensionality, where few dimensions impact function value, with sophisticated algorithms searching for and exploiting a projection, or creating random embeddings.

We avoid assuming low effective dimensionality and high dimensional modeling by optimizing sets of complimentary subspaces (that collectively exhaust the full space). Enabling intelligent information sharing amongst subspace optimizations, guiding one another to new optimal global projection locations.

#### 31 - Multi-attribute Diffusion Models for Cross-sectional Networks

Brennan Antone, Northwestern University, 2145 Sheridan Road,  
Evanston, IL, 60208, United States, Alina Lungescu,  
Noshir Contractor

We propose a statistical model for stochastic diffusion processes involving the simultaneous spread of multiple attributes based on patterns of social connections and interaction frequency. We apply this model to the spread of contraception use in rural Kenya. Our model showed the spread of contraception use was dependent upon the diffusion of different beliefs (attitude towards contraception use, subjective norms, perceived behavioral control) throughout the population, the most influential of which was attitude towards contraception use. We discuss how data-driven optimization, using posterior distributions obtained from our model, can be applied to plan social interventions.

#### 32 - Recent Advances on Solving Generalizations of the Single Item Capacitated Lot-sizing Problem

Kartik G. Kulkarni, Virginia Tech, 1215 J, Progress Street NW,  
Blacksburg, VA, 24060, United States, Manish Bansal

In this talk, we present our recent advances on solving a generalization of the classical single-item economic lot-sizing problem where the total production capacity in each period can be the summation of some binary multiples of several capacity modules of different sizes. We also develop a new algorithm for the lot-sizing problem with piecewise concave production costs and concave holding costs. Finally, we present results of our computational experiments performed on the aforementioned problems.

#### 33 - Different Decompositions in Random Coefficient and Mixed Integer Programming

Kaichen Hsu, National Tsinghua University, No. 101, Section 2,  
Kuang-Fu Road, Hsinchu, Taiwan 30013, R.O.C., Hsinchu, Taiwan

Decompositions are the approach to solving large-scale optimization programs. This approach decomposes the original optimization problem into the master problem and the subproblem. Then the master problem and the subproblem can be solved more efficiently on an iterative basis. We have an original problem which is to estimate a BLP-type random coefficients discrete choice model, a popular utility function used in economics in recent 20 years, formulated as a constrained optimization with mixed integer variables. This study attempts to solve this model more efficiently by various decompositions.

#### 34 - A Trilevel Optimization Model for Resilient Transportation Network Design

Mohammad Rahdar, Assistant Professor, St. Ambrose University,  
Davenport, IA, United States, Lizhi Wang, Guiping Hu

We propose a trilevel optimization model for transportation network design, which improves the resiliency of the network against uncertain disruptions. The middle and bottom levels are the network interdiction problem, in which we identify the worst-case scenario disruptions that could lead to a maximal cost to the transportation system. The top level takes the system perspective, which designs the optimal strategy to expand the existing transportation network so that it confronts the worst-case scenario disruptions in the most resilient manner. We also designed an iterative algorithm to solve the trilevel optimization model.

#### 35 - Optimal Placement of a Small Order in a Diffusive Limit Order Book

Hyoeun Lee, 725 S. Wright St, Champaign, IL, 61820,  
United States, J. Figueroa-Lopez, R. Pasupathy

We study the optimal placement problem of a stock trader who wishes to clear his/her inventory by a predetermined time horizon by using a limit order or a market order. For a diffusive market, we characterize the optimal limit order placement policy and analyze its behavior under different market conditions. In particular, we show that, in the presence of a negative drift, there exists a critical time horizon such that, for any time horizon longer than the critical time horizon, there exists an optimal placement, which, contrary to earlier works, is different from one that is placed infinitesimally close to the best ask, such as the best bid and second best bid. We also propose a simple method to approximate the critical time horizon and the optimal order placement.

#### 36 - Integration of Variable Micro-grid Energy to Attain Carbon Neutral Manufacturing: A Machine Learning Approach

Fei Sun, Texas State University, Austin, TX, 78750, United States,  
Tongdan Jin, Clara Novoa

This study aims to formulate a stochastic model that minimizes one-time investment and operation costs when variable renewable generators and hybrid energy storage systems are integrated into large manufacturing facilities. Various design constraints are considered, including zero carbon footprint, reliability of power supply, and battery state of charge. The objective function is a mixed integer linear programming (MILP) model. The results can provide a reference for the capacity optimization of wind, solar and energy storage systems. The variation of microgrid costs for time of use rate and battery's depth of discharge levels are analyzed as well.

**37 - Research on Baoji'S Titanium Industry Chain Patent Navigation Based on Social Network Analysis Method**

Hongru Yan, Northwestern Polytechnical University, Xi'an China, China

Patent right is the industrial intellectual property right which can best reflect the innovation level of science and technology. This paper collected and retrieved the patent information of Baoji titanium industry from 2012 to 2016 and used patent centrality analysis and patentee centrality analysis to clarify the research highlight of this field and relationship between main patentees. Finally, conclusions and recommendations have been given from 4 aspects, which contains focusing on the downstream development of Baoji titanium industry chain, facilitating the high-end extension of Baoji titanium industry chain and so on.

**38 - Stochastic Corrective Risk-based Optimal Power Flow**

Thanh To, Clemson University, Clemson, SC, 29631, United States

We propose a model that quantifies and controls the total system line overflow caused by contingencies via means of Conditional Value-at-Risk (CVaR) constraint. We then incorporate the wind uncertainty into our model and perform computational experiments.

**39 - A Case Study on Condition-based Maintenance through Machine Learning on Sensor Data**

Bram Steurtewagen, Ghent University, Steenweg Deinze 124a, Nazareth, 9810, Belgium

In the petrochemical industry, we encounter a vast landscape of sensor data that is not being used to its full potential. This data, enabled by the increase in processing power and analytical frameworks over the years, can be utilized to create predictive models and perform root cause analysis where before these domains lacked statistical and numerical input. This case study aims to implement Industry 4.0 standards by leveraging analytical techniques on real sensor data for predicting machinery failures and identifying possible causes of breakdowns. The research shows that this approach can match plant operator instincts while also providing new insights and a more fine-tuned triggering process.

**40 - Optimal Planning of the Joint Placement of Photovoltaic Panels and Green Roofs Under Climate Change Uncertainty**

Mohammad Ramshani, University of Tennessee, Knoxville, TN, 37920, United States, Anahita Khojandi, Xueping Li, Olufemi A. Omitaomu

Photovoltaic (PV) panels directly convert sunlight into electricity; but, sunlight also heats the panels, negatively impacting their efficiency. Green roofs are vegetative layers grown on rooftops, mainly to provide added insulation on the roof to save energy. Green roofs also cool near-surface air temperature. Hence, the joint installation of PV panels and green roofs may potentially lead to higher efficiency of PV panels in certain climates. We develop a two-stage stochastic programming model to optimally place PV panels and green roofs under climate change uncertainty to maximize the overall profit from energy generated and saved.

**41 - Integrating Multimodal Transport into Bioethanol Supply Chain Design Under Supply and Demand Uncertainties**

Yong Shin Park, St. Edward's University, Austin, TX, United States, Yuan Xu

A mixed integer two-stage stochastic optimization model was developed that integrates multimodal transport into the lignocellulosic-based bioethanol supply chain in an uncertain decision environment. The goal was to maximize the expected profit to support strategic and tactical decision planning. A case study based on North Dakota state in the U.S. was tested to explore the potential of multimodal transport for bioethanol supply chain. The model captures the challenges with supplying biomass to a biorefinery and shipping biofuel to demand centers under supply and demand uncertainty. Sensitivity analyses was performed to gain managerial insights on how profit changes due to uncertainties.

**42 - Deviations Between the Chinese and International Gold Price: Role of Fundamentals, Contagion and Financial Shocks**

Zhicheng Liang, HKU, Hong Kong, Hong Kong, Junwei Wang

China has been both the world's largest gold producer and consumer since 2013. With the second largest exchange-traded market in the world, however, China's gold price frequently diverges from international gold price. This study explores the impact of fundamentals, contagion and financial shocks on the price gap using an extended GARCH model. The empirical study shows that the exchange rate of renminbi plays an important role in moving the price gap. The global contagion factors associate more with the level than the volatility of the price gap. For financial shocks, policy shocks do not present significant influence on the price gap, but black swan events do.

**43 - Robust Portfolio Optimization with Options**

Hedieh Ashrafi, Southern Methodist University, EMIS, PO Box 750123, Dallas, TX, 75275-0123, United States, Aurelie Thiele

We consider the problem of maximizing the worst-case return of a portfolio when the manager can invest in stocks as well as European options on those stocks, and the stock returns are modeled using an uncertainty set approach. We present theoretical results regarding the structure of the optimal allocation as well as numerical results comparing our approach to several benchmarks, showing that our approach performs well in practice.

**44 - A Machine Learning Approach to Optimize Risk Prediction and Binary Classification for Medical Diagnosis**

Minmin Zhang, University of Michigan, Ann Arbor, MI, 48105, United States, Zheng Zhang, Brian T. Denton

We present a new continuous optimization model which maximizes the accuracy of classification and prediction respectively in different risk regions. We show that the cost function is continuously differentiable under appropriate parameters. Our proposed model offers improvements over common approaches such as regression and Lasso on the basis of true positive and true negative classification rates and calibration measured by the Brier Score in different risk regions. We illustrate our approach based on real data in the context of medical diagnosis.

**45 - Improving Non-monotonicity Issues in Predicting Survival Probability of Transplant Patients**

Hamidreza Ahady Dolatsara, Auburn University, Auburn, AL, 36830, United States, Fadel Mounir Megahed, Ying-Ju Tessa Chen, Richard Seseck, John Evans, Ashish Gupta

This study describes non-monotonic issues in predicting survival probabilities of transplant patients over a time horizon. Survival estimates of patients receiving heart transplants over a consecutive time horizon are evaluated. Various non-monotonicity issues are first investigated. Isotonic regression is adopted to resolve these issues. Prediction performance of before and after utilizing isotonic regression is finally analyzed.

**45B - Competitive Pricing of Sea and Rail Transport Based on the Selection of Shippers**

WeiDong Dai, School of Transportation and Logistic, Southwest Jiaotong University, Chengdu 611755, Sichuan, China, Chengdu, China

Railway pricing is vital to the development railway. To a certain degree, the partaking rate is determined by price. It is important to establish tariffs reasonably. This essay introduces the factors that customers will consider when choosing means of transportation, and constructs a generalized cost function. Then, we use logit model to determine the market share rate of various means of transport, and we build a game model based on the revenue maximization of various means of transport. Finally, we use Chengdu-European Express Railway and a shipping company as an example to analyze to obtain the equilibrium freight rates and sharing rates of Chengdu-European Express Railway and shipping company.

**46 - Automatic Surrogate Modeling for Complex Engineering Systems**

Reza Alizadeh, University of Oklahoma, Norman, OK, United States

There are three major selection steps in surrogate modeling, including the surrogate type, metrics and test problems. From the critical evaluation of the literature, we identified two main gaps: 1) The multiple surrogate always composed by KRG, RSM and RBNN. No research studied whether there is any other types of multi-surrogate can perform better; 2) Although many comparison works have done, there are no ruled-based knowledge generated to guide others to select a better surrogate model for their problem. Results show that Multi-surrogates has the highest accuracy and robustness. Also, the generated rules are inputs for a knowledge-based platform to make the surrogate modeling process automated.

**47 - Online Learning for Stochastic Game with Risk Preferences**

Wenjie Huang, National University of Singapore, Singapore, Singapore, Pham Viet Hai, William Haskell

In this work, we study the stochastic games considering risk preferences of different players. We show the existence of risk-aware Markov perfect equilibrium and develop a reinforcement learning type algorithm to solve the equilibrium online. Our algorithm is based on solving stochastic saddle-point problem for risk estimation and doing Nash Q-learning for finding the equilibrium. We show that our game model covers wide class of risk measures and we derive the almost sure convergence and computational complexity result for our algorithm.

**48 - Optimization of Preferred Boarding Groups by Markov Chains**

Viacheslav V. Kalashnikov, Professor & Researcher, Tecnologico de Monterrey, (ITESM), Campus Monterrey, Ave Eugenio Garza Sada 2501 Sur, Monterrey, Nuevo Leon, 64849, Mexico, Edgar Camacho-Esparza, Nataliya Kalashnykova, Vladik Kreinovich

Examine a bilevel optimization problem, in which the upper-level is an airline's management governing the price and proportion of preferred boarding passes (PBP) available. Passengers seek the equilibrium at the lower level of the model by maximizing their payoff functions thus generating a Markov chain's transition matrix. The steady-state probabilities of the Markov chain are used at the upper level as the powers of the pertinent classes into which the set of passengers is partitioned. The existence of solutions has been established and simple numerical experiments made. As a result, some practical recommendations concerning the optimal portions of PBPs and their price can be developed.

**49 - An ALNS Algorithm for the Port Scheduling Problem**

Erik Orm Hellsten, DTU, Boulevarden 14, 75, Lyngby, 2800, Denmark

The problem of routing vessels within larger ports was developed together with industry and modelled as a routing open shop problem with additional constraints. High quality solutions, to instances with up to 12 terminals and 30 vessels, were generated using an ALNS algorithm. The problem is strongly NP-hard, and to our knowledge, there exists no previous studies of it.

**50 - Towards Bridging the Gap Between Business Model Innovation and Practice Using Hypergraph Based Modeling**

Mahei Manhai Li, University of Kassel, Pfannkuchstrasse 1, Kassel, 34121, Germany, Sissy-Josefina Ernst, Christoph Peters, Christoph Peters, Jan Marco Leimeister, Jan Marco Leimeister

A hypergraph-based modeling of businesses bridges the gap between business model innovations and its implementation into enterprise solutions. By formalizing resources, actors, activities (processes) and functions into one model, their relationships are clearly defined, while encompassing both the data and processual structure. A database-based graphical tool supports system analysts and decision makers to structure and analyze their business model and corresponding value proposition. This model can thus be used for future implementations.

**51 - The Use of FPGAs for High Performance Discrete Simulation**

Ed Ramsden, Murata Power Solutions, Attleboro, MA, 02703, United States

While discrete-event/discrete-time simulations are normally run on general purpose computers, there are cases in which specialized hardware can be used to increase runtime performance by orders of magnitude. This paper presents an example of such a specialized processor designed around a Field-Programmable Gate Array (FPGA). The processor in this example models passenger boarding of an aircraft.

**52 - Improved Placement of Drinking Water Treatment System Infrastructure to Meet Conflicting System Objectives**

Sara Schwetschenau, Carnegie Mellon University, 129 Baker Hall 5000 Forbes Ave, Pittsburgh, PA, 15213, United States, Jeanne VanBriesen, Jared L. Cohon

Drinking water systems are modified over time to meet changing regulatory and urban requirements. Planning for expensive and long-lived water infrastructure is a complex decision problem. Here, a multi-objective optimization model is combined with a water quality simulation model to evaluate the location and size of drinking water system improvements.

**53 - Understand The Relations of Regional Freight Transport Structure and Carbon Emissions**

Dandan Li, Southwest Jiaotong University, Chengdu, 610031, China, Mi Gan, Mingfei Wang

Aims on comprehensively study the economic and environmental impact of freight structure. In this paper, the economic effect and environmental effect are respectively measured by economic output value per unit freight turnover and carbon emissions per unit freight turnover based on the panel data model. Our results indicate the economic output value per unit turnover, carbon emissions per unit turnover, and carbon emission intensity remarkably varies by transportation modes and regions, point out how to optimize the regional freight structure accordingly.

**54 - Spatialtemporal Evolution and Influencing Factors of Inland Port's Hinterland**

Ronghui Xie, Southwest Jiaotong University, Chengdu, 610031, China, Mi Gan, Qinglan Huang

As the implementation of Belt and Road Initiative, the strategic position of inland port in international trade has been significantly improved. However, few papers can be found exploring the evolution of hinterland of inland port among the previous studies. This paper intends to depict spatial-temporal features to catch space-time evolution that how hinterland's attraction in inland port develops. Furthermore, this paper aims to propound some optimal suggestions to promote regional development in inland areas through analyzing the macroeconomic policies to find crucial factors influencing the evolution of hinterland.

**55 - Evaluation of Regional Logistics Development Level by Multisource Data**

Xinyuan Li, Southwest Jiaotong University, Chengdu, 610031, China, Mi Gan, Fadong zhang

Based on multi-source data, this paper studies the development level of logistics industry and the spatial structure of logistics network in Sichuan Province. At first, factor analysis is used to analyze the economic and trade level, logistics market size, logistics infrastructure construction and information level. Then, based on the data of road freight O2O platform, the spatial distribution of freight resources is presented through data visualization method. Finally, comprehensively analyze the relationship between the logistics competition level of each city and state and the spatial distribution of freight resources.

**56 - Spatiotemporal Distribution Analysis of Carbon Emissions and Energy Efficiency Driving Factors of China Railway Cold Chain Logistics**

Mingfei Wang, Southwest Jiaotong University, Chengdu, 610031, China, Mi Gan, Dandan Li, Qian Zhang

Based on the traditional carbon emissions formula of the transportation industry, this paper designs a carbon emission formula for railway cold chain transportation(RCCT), and calculates the carbon emissions of China's RCCT from the provincial level using the waybill data from 2014 to 2016. Then, the SBM model and TOBIT model are employed to estimate the energy efficiency and the driving factors of energy efficiency of China's RCCT. The results give out a detailed Spatiotemporal Distribution Characteristics of china's RCCT, and show that urbanization level, railway cold chain construction level and industrial structure are positive factors to improve the energy efficiency of RCCT.

**57 - Solving the Rich Train Timetabling Problem with Complex Constraints Model Reformulation for Dual Decomposition**

Yongxiang Zhang, Southwest Jiaotong University, Chengdu, 610031, China, Qiyuan Peng, Xuesong Zhou, Yu Yao

We introduce the rich train timetabling problems (RTTP) that extends the scope of the standard train timetabling problem by incorporating multiple complicating constraints. We develop a modeling framework to prebuild those complex "rich constraints as state transition relationships into a well-structured hyper-network, so that the resulting optimization model can be nicely reformulated as multi-commodity network flow models with capacity constraints. A novel dual decomposition method is adopted to handle the reformulated network flow optimization problem. Numerical experiments are conducted to demonstrate the advantages of the proposed reformulation method and solution algorithms.

**58 - Study on the Government Subsidies and Exit Mechanism for China Railway Express Based on the Tripartite Game**

Qisheng Zhang, Southwest Jiaotong University, Chengdu, China, Yinying Tang, Yang Ge

CHINA RAILWAY Express has an important place and the great prospects in "The Belt and Road Strategy. However, due to the start-up phase, it is now faced with the problem of subsidy for increasing competition. From the perspective of government, the reasonable setting of financial subsidies is considered, through the Tripartite Game between the government, the company and the shipper; On the basis of incentive mechanism design and freight volume forecast, the rational subsidy method and exit plan are studied, in order to achieve sustainable development.

**59 - The Investigation and Analysis on Inter-city Passenger Rail Travel – A Case Study on Chengyu Region from China**

ZiShuai Pang, Southwest Jiaotong University, Chengdu, China, Liwen Wang, Shihang Zhang, Anjun Li, Dian Wang, Qiyuan Peng, Siyu Tao

Based on the intercity rail trip chain survey in Chengyu region in China, several problems has been found in the whole travel, such as long railway waiting time, multi-security checking, inconsistent ticket system, and long transfer distance. The aims are to identify the problems in the inter-city trip chain, and propose corresponding improvements base on scenario analysis. It can achieve the aim that reducing the travel link, saving the intercity rail travel time and gaining economic benefits. The combination scenario 7 could reduce the total travel time by 42.29 minutes, decrease time ratio of inner-city travel to 37.2%, along with economic benefits achieved 30.64 million yuan per year.

**60 - Analysis and Calculation for Subway Network Capacity Base on Simulation**

Feifan Jia, PhD Candidate, Beijing Jiaotong University, Beijing, China, Haiying Li, Xi Jiang, Lingyun Meng

The analysis and calculation of subway network capacity is one of the core issues of network operation. From the perspective of passenger demand and service level, we built a conceptual model of subway network capacity calculation problem. A method to calculate network capacity based on pressure test and simulation experiment was designed. And we studied the problems of service level determination and passenger loading in the algorithm and gave the steps of the algorithm. Taking Beijing subway network for example, the network capacities under different service level in peak hours were calculated. Finally, we analyzed where the bottlenecks of Beijing way network are.

**61 - Study on Optimization of China-EU Regional Supply Organization Based on Spatial Arrangement**

Xuqiang Li, Southwest Jiaotong University, Chengdu, China, YinYing Tang, qisheng zhu

In order to effectively and uniformly integrate the China railway express that have been successively implemented in various regions, this paper uses the method of the division of the traffic zone to divide the supply-state space of each region to a certain extent, and then adopts the method of fuzzy cluster analysis to supply the goods according to the relevant indexes. The district conducts analysis and integration, and analyzes the evolutionary results and impacts after its integration, and finally determines a more reasonable goods organization and the operation plan of railway freight trains. Key words: Traffic Zone; State Space; Fuzzy Cluster; Evolutionary



**62 - Analysis on the Competition Between Inland Ports Under Carbon Emission Constraints**

Qinglan Huang, Southwest Jiaotong University, Chengdu, 610031, China, Mi Gan, Ronghui Xie

With the progress of One Belt And One Road strategy, the construction of inland ports has become more and more popular, and the competition between them has become increasingly fierce. But reducing carbon dioxide emissions is one of the most important tasks of the 21st-century society. Therefore, this paper establishes a Hotlin model to describe the competitive relationship between the two inland ports, then respectively analyze the competition when one port price increasing or both inland ports price increasing under the limitation of the cap and cap-and-trade carbon emissions policy. For enterprises and the government, it also provides a basis for decision-making.

**63 - Data Driven Equilibrium Pricing and Ordering in a Multi Leaders One Follower Game**

Yong Ge Yang, National Tsing Hua University, Phoenix Arizona, Hsin Chu, 30071, Taiwan

This study constructs a multi-leader-one-follower game-theoretic model of supply chain. We consider three roles in a supply chain, which are one supplier, multiple retailers, and aggregate consumer. Retailers will be the leaders. Consumer play as the follower. Leaders keep conjecturing about the demand of followers. Retailers face the uncertain demand. We investigate the Nash equilibrium of the price competition between retailers with pricing and ordering decisions. We embed this game to a data-driven algorithm with censored demand.

**64 - Vertical Information Acquisition and Horizontal Information Sharing Strategy in a Supply Chain**

Jianghua Wu, Renmin University of China, School of Business, Beijing, 100872, China, Fan Jiang

We study the vertical information acquisition and horizontal information sharing strategy in a two-echelon supply chain, which consists of one upstream manufacturer and two downstream retailers. The study shows that retailers have no incentives to share information with manufacturer voluntarily, and we identify conditions under which full information acquisition can be achieved as long as with information acquisition the total supply chain is better off. Moreover, we show that market variation, boundary equilibrium and the competition mode (Cournot or Bertrand) in the downstream play a significant role in determining whether the competing retailers will share information with each other.

**65 - Delivering Big and Bulky Items Quickly**

Melissa Quinton, University of Arkansas, Fayetteville, AR, United States, Olivier Kwizera, Yue Wang, Joseph Geunes, Sarah G. Nurre

One factor influencing the shift from retail store to online shopping is the availability of quick and cheap shipping. Notably, Amazon prime members receive small to medium sized items in 2 days for free. We examine the necessary supply chain design for quickly delivering big and bulky items, such as appliances and furniture. For different big and bulky segments and delivery services, we determine where and how much inventory should be held to enable guaranteed committed delivery times. We present the trade-off analysis between cost and delivery time by geographic region and demand level.

**66 - Conjoint Analysis on the Use of Crowd Sourcing Model in Last Mile Delivery for CEP Services**

Mingwei Guo, North Dakota State University, UGPTI, Fargo, ND, 58105, United States, mingweigu@live.com

Last mile delivery Crowd-sourcing model would effectively improve the efficiency and mitigate the cost for CEP service providers, but actual market response may differ from our numerical results. From a customer perspective, the quality of the delivery service contains not only time and accuracy, but also the overall experience and level of convenience. If hybrid model is to be used by those customers, the quality and satisfaction of the service may be influenced by the change of staff. This study is designed to evaluate and estimate the direct and indirect impact on customer experience if hybrid models/scenarios are utilized by CEP service providers.

**67 - The Conflict Free UGV Routing in an Autonomous Warehouse**

Mona Issabakhsh, University of Miami, South Miami, FL, 33143, United States, Seokgi Lee

High labor manufacturing costs have brought a significant amount of attention to smart robotic warehouse management systems, where tasks are done by autonomous unmanned ground vehicles (UGVs). We present a mathematical UGV routing model with battery recharge schedules, which prevents multiple UGV collisions while minimizing costs of routing and energy consumption.

**68 - How Calculative are Managers when Evaluating Signals: An Empirical Examination of Signaling Theory in Trust Formation in a Supply Chain**

Pook Carson, Associate Professor, Salt Lake Community College, Salt Lake City, UT, 84123, United States

Formal models in the management sciences assume a calculative worldview. We experimentally examine how calculative managers are when trusting a supply chain partner. We distinguish between fully-calculative, non-calculative, and signaling/credibility models. The results show that interpretations are influenced by credibility which overwhelms the effect of history. Partner replaceability decreases trust from credible signals as attributions are made to external market

incentives not type. Participants do not distinguish between costly past behavior and bonds as signals. Managers are calculative, but less forward-looking than strong-form calculative approaches suggest.

**69 - Using Board Game in Supply Chain Management Classes**

Ziping Wang, Morgan State University, Baltimore, MD, United States

This poster discusses the invention of an instructional board game in supply chain management (patent pending). Data from controlled experiments are studied to show the performance of the board game in supply chain management learning.

**70 - Component Procurement and End-product Assembly with Demand and Supply Uncertainty, Using Spreadsheet Based Optimization Models.**

Ramesh Bollapragada, Professor, San Francisco State University, San Francisco, CA, 94132, United States

This paper presents the planning and coordination of component procurement and end-product assembly in a supply chain. Using linear programming models in the framework of Excel spreadsheets, we identify the effect of problem parameters on performance measures such as: inventory, shortage costs, trade-offs involving the total expected costs, the quantity of each component, and end-product to produce in a time horizon. We show through our experimentation that the highest cost drivers are product shortage costs and shared component ordering costs. Further, we show that the component inventory and purchasing decisions are sensitive to lead time increases.

**71 - The Spatial Structure Relative Research Between the Development of Regional Industries and the Logistics Demand in Sichuan Province of China**

Xiaozhen Deng, Southwest Jiaotong University, Chengdu, China, Si Chen, Mi Gan

With the evolution of regional industrial structure, the regional logistics demands generate new industrial correlation characteristics of spatial distribution, which are influenced by the spatial and temporal distribution characteristics of the industries. And those characteristics have important reference value for regional industrial layout and allocation of logistics facilities. With 21 cities as the study area and the three industries and the logistics demands of each cities data as data sources. The methods of spatial auto-correlation and regression analysis are used to do spatial and temporal characteristics correlation analysis between logistics demand and regional Industrial.

**Exhibit Hall Poster Competition  
Monday Poster Competition**

Competition Poster Session

Chair: Neng Fan, University of Arizona, 1127 E. James E. Rogers Way, P. O. Box 210020, Tucson, AZ, 85721, United States

Co-Chair: Junming Yin, University of Arizona, Management Information Systems Department, McClelland Hall, Room 430BB, Tucson, AZ, 85721, United States

Co-Chair: Burcu B. Keskin, University of Alabama, 4138 Meretta Lane, Tuscaloosa, AL, 35406, United States

**1 - IoT and Connected Vehicle Analytics for Intelligent Air Quality Management**

Oleg Gusikhin, Ford Motor Company, Research & Innovation Center, Dearborn, MI, 48121, United States, Omar Makke

Air quality is an increasing concern as urban areas continue to grow. For automotive industry, protecting vehicle occupants from pollution is a critical area of competitive advantage. This work illustrates how advancements in IoT sensors, connected vehicles technology and analytics enable intelligent cabin air quality management and optimized filter maintenance.

**2 - Directed Exploration in PAC Model-free Reinforcement Learning**

Min-hwan Oh, Columbia University, New York, NY, 10027, United States, Garud N. Iyengar

One of the fundamental challenges in Reinforcement learning (RL) is how to balance exploration and exploitation. We study an exploration method for model-free RL that generalizes the counter-based exploration bonus methods and takes into account long term exploratory value of actions rather than a single step look-ahead. We propose a model-free RL method that modifies Delayed Q-learning and utilizes the long-term exploration bonus with provable efficiency. We show that our proposed method finds a near-optimal policy in polynomial time (PAC-MDP), and also provide experimental evidence that our proposed algorithm is an efficient exploration method.

### 3 - Identifying and Visualizing Uncommon Customer Response on Machine Learning

Seung Wan Seo, Korea University, Seoul, Korea, Republic of.,  
Deokseong Seo, Myungjun Jang, Jaeyun Jung, Pilsung Kang

Detecting and visualizing uncommon but notable opinions from a large amount of Voice of Customers (VOC) data, is an important procedure in response to customer complaints. In this study, we propose a framework for identifying uncommon but significant responses and frequently used words in them based on distributed document representation, local outlier factor, and TF-IDF methods. We also propose a result visualization procedure that can provide useful information to vehicle engineers. This uncommon response detection and visualization framework can accelerate the efficiency and effectiveness of a large amount of VOC data analytics.

### 4 - Deep Learning Based Damage Detection on Post-hurricane Satellite Imagery

Quoc Dung Cao, University of Washington, Seattle, WA, 98105-0002, United States

After a hurricane, damage assessment is critical to emergency managers and first responders. To improve the efficiency and accuracy of damage assessment, instead of using windshield survey, we propose to automatically detect damaged buildings using image classification algorithms. The method is applied to the case study of 2017 Hurricane Harvey.

### 5 - A Systematic Architecture Definition Methodology for Engineering Prognostic and Health Management System

Rui Li, Delft University of Technology, Delft, Netherlands,  
Wim J.C. Verhagen, Richard Curran

Prognostics and health management (PHM) has become a crucial research in many engineering fields, enabling fault diagnostics, prognostics remaining useful lifetime and health management. However, the characteristics of PHM architecture methodology have not been dealt with in depth. To fill the gaps, this research defines a systematic architecture definition methodology for engineering a PHM system.

### 6 - Optimal Inventory Distribution Strategy for Relief Supply Considering Information Uncertainty after a Major Disaster

Riki Kawase, Kobe University, Nada, Kobe, Hyogo, Japan

Humanitarian supply chain management plays an important role in addressing major disasters. However, timely supply was impossible because of mismatching of the needs and the bottleneck of the last mile. Now, two types of plans have been proposed: (1) Direct distribution and (2) Kanban system, but no mathematical analysis has been done. Our research conducts mathematical analysis on these empirical proposals. Specifically, we find the optimal strategy of the inventory distribution problem using the optimal control theory. We analyze the optimal control and clarify the effectiveness of proposal (1). Additionally, numerical example shows that updating information can make the system worse.

### 7 - Optimal Switching Sequence for Switched Linear Systems

Zeyang Wu, University of Minnesota, Minneapolis, MN, 55414-2922, United States, Qie He

We study a mixed-integer nonlinear optimization problem. This problem has many applications in operations research and control, yet a moderate-sized instance is challenging to solve to optimality for state-of-the-art optimization software. We propose a simple exact algorithm for this problem. Our algorithm runs in polynomial time when oligo-vertex property, a concept we introduce in this paper for a set of matrices, is satisfied. We derive several sufficient conditions for a set of matrices to have the oligo-vertex property. Numerical results demonstrate the clear advantage of our algorithm in solving large-sized instances of the problem over one state-of-the-art global solver.

### 8 - Integrating Vehicle Routing and Scheduling to Optimize Foster Care Visitations

Caroline M. Johnston, Worcester Polytechnic Institute, Worcester, MA, 01609, United States, Shima Azizi, Katherine Dunphy, Renata Konrad, Andrew C. Trapp

We have partnered with a county in New York State that oversees approximately 100 foster care cases, each requiring the transportation of children to weekly/bi-weekly meetings with biological parents and case workers at an assigned meeting time. The current driver/case worker assignment system is executed manually in a cumbersome manner. We model this problem using combinatorial optimization concepts such as the Dial-A-Ride and team orienteering problems with the goal of maximizing the throughput of cases seen per week. Our goal is to create a decision-support tool to recommend weekly driver/case worker assignments to facilitate this scheduling process, increasing the quality of this system.

### 9 - Virus Spread Over Networks

Philip Pare, University of Illinois at Urbana Champaign, Urbana, IL, 61801, United States, Carolyn Beck, Angelia Nedich, Tamer Basar

Virus models over non-trivial networks are commonly motivated by biological, computer, and human contact networks. Developing spread models over networks that can be analyzed and validated can help develop efficient mitigation techniques. Previous study of spread models has been done, however, learning the spread parameters of such models has not yet been explored, and the models have not been validated by real data. We present several analysis results, employ John Snow's seminal work on cholera epidemics in London in the 1850's to validate a network-dependent susceptible-infected-susceptible (SIS) model, and present a control heuristic for mitigating the spread of an epidemic.

### 10 - The Reliable Facility Location Model Considering Dependent Supporting Structure

Prakash Jamar Kattel, Ohio University, Athens, OH, 45701, United States, Felipe Aros-Vera

This research develops a mathematical optimization-based framework to determine the optimal location of a critical facility in interconnected networks. This is important since the failure of a single facility in a network might produce cascading failures in interdependent Critical infrastructures and produce negative social and economic impacts.

### 11 - Optimization of Food Pantry Locations to Address Food Scarcity in Toledo

Ece Sancı, University of Michigan, Ann Arbor, MI, 48105, United States, Sharanya Chandran, Jie Ma, Emily Morris, Jeremy Pasteris

Food for Thought (FFT) is a nonprofit organization working in downtown Toledo and surrounding areas. FFT works to alleviate food scarcity among food insecure households. In this study, we propose an optimization model to help FFT determine optimal timing and locations for their pantry deployment.

### 12 - Mixed Strategy Nash Equilibrium (NE) for Flight-frequencies Competition in Airlines Market

Chun-Han Wang, National Tsing Hua University, Hsinchu, Taiwan  
Yu-Ching Lee, Yue Dai

In airlines market, each company competes on flight-frequencies and airport time slots to pursue higher profits. We construct equilibrium programming models to compute the exact NE flight-frequencies, including basic model where each airline acts as a player and alliance model where each alliance acts as a player. It is known that there may not exist a pure strategy NE. Therefore, mixed strategy NE is formulated instead. We anticipate to get existence result, expected total profits for each player, and a suggested percentage of code-share flights of each airline within an alliance.

### 13 - Learning and Analysis of Precedence Network Based on Coupon Subset Collection Problem

Xiaotian Xie, University of Illinois at Urbana Champaign, Urbana, IL, 61801, United States, Vincent Hoff, Carolyn Beck

We infer manufacturing precedence relationships using process data, where sequenced subassembly tasks are viewed as nodes, and edges represent precedence constraints between tasks. Given subassembly begin and end times, we identify precedence relationships to analyze differences in planned versus implemented processes. Contributions include inference algorithms and corresponding sample complexity analyses.

### 14 - Niche Centrality and Compression in Competitive Organizational Networks

Brian Aronson, Duke University, Durham, NC, 27705, United States

Organizations compete across many dimensions and at varying intensities, resulting in complex structures of competition. Prior work finds that organizations' survival chances are influenced by population dynamics across broadly-defined organizational niches; however, less is known about patterns of competition within such niches. This paper constructs a new model for studying competitive organizational networks and hypothesizes two structural mechanisms that influence organizations' survival chances: Niche centrality and compression.

### 15 - Equitable Pricing of Episodes of Care in a Cluster-based Bundled Payment System

Bikram Partap Singh, M.S. Candidate, Rochester Institute of Technology, Rochester, NY, 14623, United States, Ruben A. Proaño

This study proposes a systemic approach to simultaneously price multiple episodes of care under a cluster-based bundle payment framework. We present a multi-criteria optimization model that makes highly expensive episodes of care more affordable by reallocating revenue expectations among less expensive clusters of encounters for different episodes of care.

**16 - Evaluation of Primary Care Delivery with E-visits**

Aditya Mahadev Prakash, University of Florida, 473 Weil Hall,  
Gainesville, FL, 32608, United States, Xiang Zhong

E-visit is a messaging service offered by physicians through patient portals. Offering e-visit entails a horizontal substitution of office visits for a segment of patients. A key problem for an institution that provides both services is to optimally allocate resources that improves patients' care-access, profitably. A queuing model with non-homogenous arrival rates is developed. Service capacity regions that improve accessibility and conditions for profitability are identified. Under high traffic, based on patient segmentation, medical institutions can equip their e-visit services with an optimal amount of resources to ensure an economical outcome while providing care to more patients.

**17 - Optimal Integration of Desensitization Protocols into Kidney Paired Donation Programs**

Fatemeh Karami, University of Louisville, Louisville, KY, 40292,  
United States, Mehdi Nayeypour, Monica Gentili, Naoru Koizumi,  
Keith Melancon

Blood type (ABO) incompatibility and antibody to donor human leukocyte antigen (HLA) remain the most significant barriers in transplantation. While pre-transplant desensitization can be administered to overcome such incompatibilities between living donors and their kidney recipients, desensitization alone is likely to fail for those pairs with significant incompatibilities. For these pairs, desensitization can be administered in combination with Kidney Paired Donor (KPD) exchange, the system that allows incompatible pairs to exchange donors with other incompatible pairs to improve donor-recipient compatibilities.

**18 - Spare Parts Estimation Using Cox Modeling**

Alejandro Najera-Acosta, Graduate Student, New Mexico State  
University, Las Cruces, NM, 88001, United States, Delia J. Valles-  
Rosales

In a competitive production environment, only those companies that consider all aspects of processes or systems performance remain competitive. Management of spare components is a key feature for the performance of maintenance activities. Spare parts constitute an essential element in all industries, they are designed for a specific use, its useful life is random, and its propagation is difficult to determine. Therefore, spare parts inventories are established to allow rapid replacement of failed parts and ensure a continuity of the operations. An approach through Cox Model is proposed for its estimation to improve accuracy in the inventory management of spare parts.

**19 - Optimal Placement of Actuators for Composite Fuselage Shape Control**

Juan Du, Peking University, College of Engineering, Beijing,  
100871, China, Xiaowei Yue, Jeffrey H. Hunt, Jianjun Shi

Actuator placement is critical and challenging for shape control due to dimensional variabilities of composite fuselages. Current practice is non-optimal and low efficient. We propose an optimal actuator placement methodology for efficient composite fuselage shape control by developing a sparse learning model and corresponding estimation algorithm. The case study shows that our proposed method achieves the optimal actuator placement for shape adjustments of the composite fuselage.

**Monday, 1:30PM - 3:00PM**

**MC01**

North Bldg 121A

**Computationally Tractable Methods for Stochastic Optimization**

Sponsored: Optimization/Optimization Under Uncertainty

Sponsored Session

Chair: Sarah M. Ryan, Iowa State University, Ames, IA, 50011-2164,  
United States

**1 - New Approaches for Solving Two-stage Stochastic Mixed-integer Programs with Continuous Recourse**

Siavash Tabrizian, Southern Methodist University, Dallas, TX,  
75206, United States, Harsha Gangammanavar, Halit Uster

In this talk we present enhancements to the L-shaped method to solve large-scale two-stage stochastic mixed-integer programs with continuous recourse. We apply sampling techniques within optimization to achieve computational improvement. We demonstrate these results on classical problems in the literature.

**2 - Robust Optimization for Linear Gaussian Processes**

Georgios Kotsalis, ISyE Ga Tech, Atlanta, GA, 30309-5413,  
United States, Guanghui Lan

We provide a computationally tractable procedure of affine policies for the constrained multistage robust optimization problem as it pertains to linear models that are subject to quadratic constraints, while being affected by uncertain

external disturbances and Gaussian noise. We derive our results under the general assumption that the external disturbances lie within some nominal range expressed as the intersection of ellipsoids centered at the origin. A particular class of problems that falls under the scope of our investigations are mass-transportation problems requiring the optimal steering of a linear stochastic system to a finite probability distribution.

**3 - Observational Data-Based Quality Assessment of Scenario Generation for Stochastic Programs**

Sarah M. Ryan, Iowa State University, 3004 Black Engineering,  
Industrial & Manufacturing Systems Eng, Ames, IA, 50011-2164,  
United States, Didem Sari Ay

The quality of stochastic program solutions depends on the quality of scenarios employed to obtain them. Given a set of historical instances, an appealing way to assess scenario generation is to conduct a backtest of the scenario generation and solution procedure, in which the cost of the optimized first-stage solution is assessed using the observed values of the uncertain parameters. Such a study may be very demanding computationally. We propose alternative approaches using past instances that do not require solving deterministic equivalents. Instead, we assess the quality of scenario sets by applying reliability metrics to the optimal costs of single-scenario subproblems.

**MC02**

North Bldg 121B

**Robust Optimization**

Sponsored: Optimization/Optimization Under Uncertainty

Sponsored Session

Chair: Michael R. Wagner, University of Washington, Seattle, WA,  
98195, United States

**1 - Robust Monitoring on Social Networks with a Application to Suicide Prevention**

Aida Rahmattalabi, University of Southern California, Los Angeles,  
CA, United States

We consider the problem of selecting "gatekeepers," with uncertain availabilities, to train as monitors capable of recognizing warning signs of suicide among their peers in a social network. We formulate the problem as a two-stage robust optimization problem that aims to maximize the worst-case number of covered nodes. We propose a practically tractable approximation scheme based on the K-adaptability idea. We demonstrate the effectiveness of our proposed approach on various network instances. In particular, we perform a case study on a real social network of college students. Finally, we illustrate how our solution can be used to inform gatekeeper training on college campuses.

**2 - Pricing Service Level Guarantees in Cloud Computing**

Chaithanya Bandi, Kellogg School of Management, Northwestern  
University, 2211 Campus Dr, Room 4169, Evanston, IL, 60208,  
United States

We consider the problem of pricing service level agreements in Cloud computing systems. We leverage tools from Robust Queueing theory and multi-stage optimization to compute the prices.

**3 - A Robust Multi-period Newsvendor Model with Inventory Balance Constraints**

Saumya Sinha, University of Washington, Box 353925, University  
of Washington, Seattle, WA, 98195, United States,  
Michael R. Wagner, Archis Ghatge

We present a robust newsvendor model that accounts for revenue in addition to the various cost parameters, thereby leading to a profit maximization problem under inventory balance constraints. We provide closed-form expressions for the optimal order quantities. This calls for the solution of the so-called inner problems, which are also solved analytically for a large class of commonly occurring uncertainty sets.

**4 - A Robust Optimization Approach to Crowdsourcing Last-mile Deliveries**

Soraya Fatehi, University of Washington, Michael G. Foster School  
of Business, University of Washington, 358 Mackenzie Hall,  
Seattle, WA, 98195-3200, United States

We propose and analyze a robust optimization model for crowdsourcing last-mile deliveries via independent drivers. In this context, our model minimizes the worst-case delivery cost of a firm, subject to delivering all customer orders on-time, with high probability. We derive the optimal proportion of packages to assign to the crowd, the optimal number of packages per driver, the optimal crowdsourced delivery area, and the optimal crowd workforce. We show that, if the crowd-delivery system is designed optimally, then the firm can significantly benefit from crowdsourcing last-mile deliveries, especially for fast same-day deliveries.



## ■ MC03

North Bldg 121C

### Innovation Contests

Sponsored: Technology, Innovation Management & Entrepreneurship

Sponsored Session

Chair: Ersin Korpeoglu, University College London, London, E14 5AA, United Kingdom

#### 1 - Parallel Innovation Contests

C Gizem Korpeoglu, University College London, Gower Street, London, WC1E 6BT, United Kingdom, Ersin Korpeoglu, Isa Emin Hafalir

We study innovation contests where multiple organizers seek solutions from agents, and the quality of an agent's solution depends on her effort and uncertainty. We find that when uncertainty is sufficiently large, organizers benefit from agents' entry to multiple contests. An organizer's profit is unimodal in the number of contests, and the optimal number of contests increases with uncertainty. Thus, practitioners who seek innovative (resp., low-novelty) solutions may benefit from running multiple parallel contests and from encouraging (resp., discouraging) agents' entry to multiple contests.

#### 2 - Dueling Crowdsourcing Contests

Konstantinos Stouras, University of Virginia, The Darden School, 100 Darden Boulevard, Charlottesville, VA, 22903, United States, Sanjiv Erat, Kenneth Lichtendahl

Solvers' participation and effort decisions in a contest are not only affected by its design, but they also depend on the design of any competing contests that run in parallel. We provide a theoretical analysis of the equilibrium budget allocation in a game played among competing innovation contests.

#### 3 - When to Involve Inhouse Suppliers in Procurement Contests

Zhi Chen, INSEAD, 1 Ayer Rajah Avenue, Singapore, Singapore, Jochen Schlapp, Jurgen Mihm

In many purchasing projects, suppliers compete by performing some custom product or technology development regardless of whether they win the project or not. In practice, two competition structures are observed in such procurement contests: (i) all participants are external suppliers; or (ii) one of the suppliers is (partially) owned by the buyer (e.g., through a joint venture). In this study, we analyze when either of these structures is optimal for a buyer seeking a custom innovation.

#### 4 - Optimal Duration of Innovation Contests

Ersin Korpeoglu, University College London, 1 Canada Square, London, E14 5AA, United Kingdom, C. Gizem Korpeoglu, Sidika Tunc

We study optimal duration and award scheme of an innovation contest where an organizer elicits innovative solutions from agents. Each agent exerts costly effort to improve her solution and faces an output uncertainty. We find that optimal contest duration may increase with novelty and sophistication of solutions that organizer seeks. We show that an organizer with moderate or high urgency in obtaining solutions may adopt winner-take-all award scheme, while an organizer with low urgency may give multiple awards. This may explain why many contests on platforms give multiple awards. Consistent with empirical evidence, we show that optimal duration and optimal total award are positively correlated.

## ■ MC04

North Bldg 122A

### Joint Session Integer Programming/OR Frontiers: Machine Learning and Discrete Optimization III

Sponsored: Optimization/Integer and Discrete Optimization

Sponsored Session

Chair: Sebastian Pokutta, Georgia Institute of Technology, Atlanta, GA, 30332-0205, United States

Co-Chair: Alfredo Torricco, Georgia Institute of Technology, Atlanta, GA, United States

#### 1 - Distributionally Robust Submodular Maximization

Matthew Staib, MIT, Bryan Wilder, Stefanie Jegelka

Submodular functions have wide applications, but we often lack direct access to the underlying function  $f$ . We focus on stochastic functions given as an expectation of functions over a distribution  $P$ . In practice, we have only finite samples  $f_i$  from  $P$ . The standard approach indirectly optimizes  $f$  by maximizing  $\sum f_i$ , ignoring generalization to  $P$ . We achieve better performance on the true function  $f$  by showing how to perform distributionally robust optimization (DRO) for submodular functions. We give efficient algorithms backed by theoretical guarantees that leverage new contributions to DRO. Our empirical evidence shows DRO improves generalization to the unknown stochastic submodular function.

#### 2 - The Benefits of Stochastic Proximal Steps

Sebastien Martin, Massachusetts Institute of Technology, Cambridge, MA, 02139, United States, Patrick Jaillet, Dimitris Bertsimas

The stochastic proximal point algorithm for convex optimization is an alternative to stochastic gradient steps that solves a convex optimization problem at each step instead of simply computing a gradient. We investigate in this work the type of optimization problems for which this algorithm is competitive with stochastic gradient descent, with a focus on the tractability of applications in machine learning. In particular, we study the impact of mini-batching and of proximal step approximations.

#### 3 - The Online Saddle Point Problem with Applications to Constrained Online Convex Optimization

Adrian Rivera, Georgia Institute of Technology, Atlanta, GA, United States, He Wang, Huan Xu

Online Convex Optimization (OCO) is a very powerful framework for sequential decision making with plenty of applications in optimization, game theory and machine learning. We generalize the framework of OCO in two ways. First, we explicitly introduce another player into the setting by considering convex-concave games, the goal of the players is to find a sequence of actions such that they are both guaranteed performance close to that of the Nash equilibrium of the sum of the games. We provide an algorithm to solve this problem. Second, we demonstrate the algorithm can be used to solve a variant of OCO where the decisions a player has made in the past affect what it can do now.

#### 4 - Learning Combinatorial Optimization Algorithms Over Graphs

Elias B. Khalil, Georgia Tech, 1062 Hemphill Avenue NW, Atlanta, GA, 30318, United States, Hanjun Dai, Yuyu Zhang, Bistra Dilkina, Le Song

The design of good heuristics for NP-hard combinatorial problems often requires significant specialized knowledge and trial-and-error. Can we automate this challenging, tedious process, and learn the algorithms instead? In many real-world applications, the same optimization problem is solved on a regular basis, with only slight changes in the data. We propose a unique combination of reinforcement learning and graph embedding to address this challenge. The learned greedy policy behaves like a meta-algorithm that incrementally constructs a solution. Our framework is versatile and has been successfully used to solve instances from Minimum Vertex Cover, Max Cut and Traveling Salesman problems.

## ■ MC05

North Bldg 122B

### Conic Optimization in Machine Learning II

Sponsored: Optimization/Linear and Conic Optimization

Sponsored Session

Chair: Somayeh Moazeni, Stevens Institute of Technology, Hoboken, NJ, 07030, United States

#### 1 - Conic Optimization in Sequential Learning

Somayeh Moazeni, Stevens Institute of Technology, Babbio Center, 1 Castle Point Terrace on Hudson, Hoboken, NJ, 07030, United States

Sequential optimal learning is a sequential decision problem with an exploration-exploitation trade-off. Building on dynamic Bayesian learning and given a learning budget, the procedure identifies effective design elements. This talk discusses conic optimization approaches to solve this problem under a general class of response models with point processes. We show that this optimization problem can be solved by a sequence of linear optimization problems. This approximation is capable to offer close to optimal solutions and significantly reduces the computational time for high-dimensional feature spaces.

#### 2 - Maximizing the Probability of an Arrival Count in Point-process Intensity Control

Boris Defourny, Lehigh University, Industrial and Systems Engineering, 200 W. Packer Ave, Bethlehem, PA, 18015, United States

We consider the maximization of the probability of attaining a prescribed count of arrivals generated by a point process, by controlling its intensity. We show that the optimal intensity control law has switching times that are affine in the arrival count, and find closed-form expressions for the policy parameters.

### 3 - Non-convex Sparse Sample Average Approximations: Properties of D-stationary Solutions

Miju Ahn, Southern Methodist University, Dallas, TX, United States

In sparse learning, sample average approximation involving non-convex sparsity functions is a method that is widely used in practice. We introduce a unified difference-of-convex formulation and study properties of the directional stationary solutions. The solution kind is compared to a vector which is possibly the global optimum of an underlying expectation minimization problem. We provide a bound for the distance between the two solutions, a bound on the difference between their model outcomes, and a result showing inclusion relationships among their support sets.

## ■ MC06

North Bldg 122C

### Joint Session OPT/Practice Curated: Pyomo: Recent Developments and Applications

Sponsored: Optimization/Computational Optimization and Software Sponsored Session

Chair: John Sirola, Sandia National Laboratories, Albuquerque, NM, 87185, United States

#### 1 - Pyomo.GDP: An Integrated Ecosystem for Generalized Disjunctive Programming Modeling and Optimization

Qi Chen, Carnegie Mellon University, 5000 Forbes Avenue, Department of Chemical Engineering, Pittsburgh, PA, 15213, United States, David Bernal, John Sirola, Ignacio E. Grossmann

In this work, we present new capabilities in Pyomo.GDP. Generalized Disjunctive Programs (GDPs) allow high-level description of optimization problems involving both discrete and continuous decision variables. For difficult problems, we must move beyond classical reformulation approaches. Pyomo.GDP offers automated application of advanced techniques such as disjunctive “basic steps and procedural reformulations. We also introduce a new direct solver for Pyomo.GDP models, GDPopt, which implements the logic-based outer approximation decomposition algorithm. We demonstrate the application of these tools on a set of GDP test problems.

#### 2 - Pyomo.dae: A Framework for Modeling and Solving Dynamic Optimization Problems

Bethany Nicholson, Sandia National Laboratories, P.O. Box 5800, MS 1326, Albuquerque, NM, 87185, United States, John Sirola

Dynamic optimization problems include differential equations as constraints. These problems can be tough to implement and solve because they must be reformulated before being sent to standard optimization solvers. Pyomo.dae is a Pyomo extension for representing differential equations in an optimization modeling context. It includes implementations of several discretization schemes that will automatically convert differential equations to algebraic equations, making the model compatible with generic optimization solvers. In this talk we describe the capabilities of Pyomo.dae and demonstrate the concise model implementations of several complex dynamic optimization problems.

#### 3 - The IDAES Framework: Process Modeling and Optimization in Pyomo

John Sirola, Sandia National Laboratories, P.O. Box 5800, MS 1326, Albuquerque, NM, 87185, Qi Chen, Ignacio E. Grossmann

A cornerstone of the Institute for the Design of Advanced Energy Systems (IDAES) is a modeling and algorithmic framework that addresses the capability gap between state-of-the-art process simulators and general-purpose algebraic modeling languages. The framework, built on Pyomo, provides an extensible process modeling environment that supports optimization-based synthesis, design, control, and uncertainty quantification. This presentation will show how Pyomo was extended into the PSE domain and highlight several case studies.

#### 4 - Mixed-integer Nonlinear Decomposition Toolbox for Pyomo (MindtPy)

David E. Bernal, Carnegie Mellon University, 5000 Forbes Ave., Pittsburgh, PA, 15213, United States, Felicity Gong, Qi Chen, Ignacio E. Grossmann

This work describes a software toolbox developed in Pyomo, a modeling and optimization application in Python, where decomposition methods for solving mixed-integer nonlinear programs (MINLP) are implemented. Decomposition methods for MINLP rely on the iterative solution of mixed-integer linear programs and nonlinear programming; which have had a steady and considerable improvement in the last years. Several decomposition methods, together with recent algorithmic improvements such as primal heuristics and quadratic cuts, are available in MindtPy. We illustrate the application of this toolbox on a set of convex MINLP problems of varying sizes and degrees of difficulty.

## ■ MC07

North Bldg 123

### Modeling, Optimizing, and Controlling Interdependent Networks

Sponsored: Optimization/Network Optimization Sponsored Session

Chair: Andres D. Gonzalez, PhD, University of Oklahoma, 202 Boyd St, Room 116b, Norman, OK, 73019, United States

#### 1 - Bayesian Hierarchical Models for Decentralized Decision-making across Interdependent Network Restoration

Hesam Talebiyan, Rice University, 6100 Main Street, MS-318, Houston, TX, 77005, United States, Leonardo Duenas-Orsorio

We propose tractable algorithms and models offering probabilistic decentralization for the realistic decision-making processes guiding the restoration of interdependent networks. We explore Bayesian Hierarchical (BH) models to embed the decision-makers’ judgment calls that guide a formal D-INDP formulation. We demonstrate our models with idealistic as well as real-world interdependent networks.

#### 2 - A Probabilistic Network Flow Approach to the Resilience Analysis of Interdependent Infrastructure Systems

Jin-Zhu Yu, Vanderbilt University, Nashville, TN, United States, Hiba Baroud

Resilience models of interdependent infrastructure systems often consider static interdependent linkages across systems, ignoring their dynamic nature and corresponding uncertainty. This study proposes a probabilistic network flow-based approach to modelling the resilience of interdependent infrastructures systems under epistemic uncertainty due to the lack of data on historical events, systems properties, and social factors. The proposed approach is illustrated using a case study of the water and power distribution systems serving Shelby County in Tennessee.

#### 3 - A Compositional Approach for Modeling and Control of Layered Networks

Siavash Alemzadeh, University of Washington, Seattle, WA, United States, Mehran Mesbahi

The analysis of large-scale networks often require the availability of models for the interactions amongst network agents. However, characterizing accurate real-world models of these interactions pose challenges due to inherent complexities. For certain classes of networks, the layering structure allows a compositional approach for modeling. We present a factorization methodology to find mathematical models and determine performance guarantees on layered networks with model uncertainties. This is viable either with the knowledge of the system parameters or through a data-driven process. Examples are provided to verify the presented methodology on modeling real-world problems.

#### 4 - Optimum Evacuation Flows during Probabilistic Network Events

Pitu B. Mirchandani, Arizona State University, School of Computing, Informatics and, Decision System, Tempe, AZ, 85287, Gita Ketut

During catastrophic events, established infrastructures are often damaged and networks become decapitated temporally and spatially. The impacts of cascading disconnectivity, particularly in transportation network, affect the performance of the other connected networks as their operations rely upon the current state of the transportation network. We propose a network flow optimization model for a spatial-temporal damaged network to determine the optimal evacuation flow from multiple origins to multiple destinations competing over the same capacitated network.

## ■ MC08

North Bldg 124A

### Joint Session OPT/Practice Curated: Network Optimization in Power Systems

Sponsored: Optimization/Network Optimization

Sponsored Session

Chair: Adolfo Raphael Escobedo, Arizona State University, Tempe, AZ, 85287-8809

#### 1 - Optimal Portfolio of Power Flow Control Technologies: Topology and Impedance Control

Mostafa Sahraei-Ardakani, University of Utah, 50 South Central Campus Drive, #2110 Merrill Engineering Building, Salt Lake City, UT, 84112, United States

High congestion costs demand for more efficient utilization of the transmission system. Topology and impedance control are two technologies that enable such efficiency gains, through controlling the power flows. As the system operators begin to utilize these tools, it is essential to understand the interdependence between them. This talk presents simulation results that suggest a strong interdependence between topology and impedance control. It is, thus, essential to acknowledge this interdependence, both at the planning and operation stage. Failure to do so will lead to economic inefficiencies that can be avoided through appropriate co-optimization.

#### 2 - Strategic Behavior of Self-scheduling Distributed Energy Resources in Energy and Reserve Co-optimizing Markets

Fatma Selin Yanikara, Boston University, 15 St Marys Street, Room 140, Boston, MA, 02215, United States, Michael C. Caramanis

We study the participation of distribution network connected, self-scheduling Distributed Energy Resources (DERs), such as EVs and wind farms, in energy and reserve markets. Important issues that arise when DERs self-schedule are existence and uniqueness of equilibrium, and strategic behavior. We study the distributed market clearing with self-scheduling DERs in game theory context and characterize the Nash equilibrium under various information availability cases: DERs are either (i) price takers or (ii) have access to local information and can explicitly calculate locational prices. Information aware DERs engage in a Nash game since they know how their own and others' actions impact prices.

#### 3 - Spatiotemporal Marginal Costs in Optimal Operational Planning of Distribution Networks

Panagiotis Andrianesis, Boston University, Boston, MA, United States, Michael C. Caramanis

The rapid growth of Distributed Energy Resources (DERs) presents a major challenge together with a still unexploited opportunity for a radical transformation of the distribution grid. We employ a distribution grid representation that captures the salient features and costs of distribution assets, as well as the complex DER preferences and capabilities, and enables the discovery of short-term dynamic locational marginal costs. We discuss the inherent difficulties of the operational planning optimization problem, and we present results from actual distribution feeders.

#### 4 - Bus-angle Difference Valid Inequalities and Algorithms for DC Power Transmission Expansion Planning

Kyle Skolfield, Arizona State University, Phoenix, AZ, United States, Laura M. Escobar, Adolfo Raphael Escobedo, Ruben Romero

To meet rising demand for electricity under limited budgets, it is necessary to determine the best Transmission Expansion Planning strategies. This problem can be modeled as a large-scale MIP whose solution is intractable. To enable efficient search of the solution space, we derive a class of angular valid inequalities (AVIs) to be incorporated as cutting planes in the root node of the branch-and-bound tree. We design a data-driven scheme guided by solutions to various relaxation models to select the most effective AVIs. We test this scheme's effectiveness via benchmark instances.

## ■ MC09

North Bldg 124B

### Methods for Large Scale Nonlinear and Stochastic Optimization I

Sponsored: Optimization/Nonlinear Programming

Sponsored Session

Chair: Albert Solomon Berahas, Evanston, IL, 60208, United States

Co-Chair: Francisco Jara-Moroni, Northwestern University, Evanston, IL, 60208, United States

#### 1 - Gauss-newton Methods for Deep Neural Networks

Yi Ren, Columbia University, 331 Mudd Bldg, I. E.O.R. Department, New York, NY, 10027-6699, United States,

Donald Goldfarb

We present several practical Gauss-Newton (Levenberg-Marquardt) methods for solving nonconvex optimization problems that arise in training deep neural networks involving enormous numbers of variables. Numerical results are presented to demonstrate the effectiveness of our proposed methods.

#### 2 - Atomic SGD: Communication-efficient Learning via Atomic Sparsification

Zachary Charles, UW-Madison, 1415 Engineering Drive, Madison, WI, 53703, United States, Dimitris Papailiopoulos

Distributed implementations of mini-batch SGD are often beset by communication bottlenecks attributed to the large gradients that are communicated between compute nodes. One possible remedy is to sparsify these gradients. We show that such a sparsification can be applied to any atomic decomposition of the gradient, e.g., element-wise, spectral-wise, etc. Given a sparsity budget, we find a closed-form expression for the sparsification scheme that minimizes variance, which controls convergence. We show that methods like QSGD and TernGrad are special cases of our method, and argue that spectral sparsification of gradients can lead to significantly less communication costs compared to QSGD.

#### 3 - Analysis of Scaled Memoryless BFGS on a Class of Nonsmooth Convex Functions

Azam Asl, 251 Mercer St., New York, NY, 10012, United States, Michael Overton

L-BFGS can be used with or without "scaling"; the use of scaling is normally recommended. In this paper we analyze L-BFGS with one update with scaling on the nonsmooth function,  $f(x) = \alpha \sqrt[n]{\sum_{i=1}^n x_i^2} + \sum_{i=2}^n x_i^2$ , in the limit the the absolute value of the normalized search direction generated by this method converges to a constant vector, and if  $\alpha$  is larger than a quantity dependent only on the Armijo parameter, then the iterates converge to a non-optimal point  $\bar{x}$  with  $\bar{x}^T \nabla f(\bar{x}) = 0$ , although  $f$  is unbounded below.

#### 4 - A Stochastic Trust Region Method

Rui Shi, Lehigh University, Bethlehem, PA, United States

In this talk, we present a new stochastic trust region method, deemed TRish, for solving stochastic and finite-sum minimization problems. We motivate our approach by illustrating how it can be derived from a trust region methodology. However, we also illustrate how a direct adaptation of a trust region methodology might fail to lead to general convergence guarantees. Hence, our approach involves a modified update scheme, which we prove possesses convergence guarantees that are similar to those for a traditional stochastic gradient (SG) method. We also present numerical results showing that TRish can outperform SG when solving convex and nonconvex machine learning test problems.

## ■ MC10

North Bldg 125A

### Online Platforms and Operations Management

Sponsored: Manufacturing & Service Oper Mgmt

Sponsored Session

Chair: Eunae Yoo, University of Tennessee, 5416 W Cindy Place, Tempe, AZ, 85226, United States

#### 1 - The Wisdom of Crowds in Operations: Forecasting using Prediction Markets

Ruomeng Cui, Emory University, 1935 Ridgmont Lane, Decatur, GA, 30033, United States, Achal Bassamboo, Antonio Moreno

Prediction is challenging when historical information is not available, such as forecasting demand of a new product. One approach that can be applied in such situations is to crowdsource opinions from employees and the public. We focus on a widely-adopted class of crowd-based forecasting tools—prediction markets. These are virtual markets created to aggregate crowds' opinions and operate in a way similar to stock markets. We partnered with Cultivate Labs. Using information extracted from employees and public crowds, we show that prediction markets produce well-calibrated forecasting results. In addition, we run several field experiments to study the conditions under which groups work well.

#### 2 - Managing Service Systems in Presence of Social Networks

Gad Allon, University of Pennsylvania, 3730 Walnut Street, Philadelphia, PA, 19104, United States, Dennis Zhang

We study a service system with the presence of a social network. In our model, firms can differentiate resource allocations among customers, and customers learn the service qualities from the social network. We study the interplay among network structure, customer characteristics, and information structure, and characterize the optimal policy. We further calibrate our model with data from Yelp.com and quantify the value of social network knowledge empirically.



### 3 - Social Media for Disaster Management: A Study of Hurricane Sandy

Lu Yan, Indiana University, 1309 E. 10th St, Bu 570c,  
Bloomington, IN, 47401, United States, Alfonso Pedraza Martinez

In this research, we use Facebook data from five benchmark organizations that responded to Hurricane Sandy, 2012 and study the social conversation between relief organizations and social media users at different disaster stages. By analyzing all the organizations' posts and users' comments, we find that informational support is most effective during disaster response. Yet, there is a mismatch between the actionable information that organizations post and the one that users are interested in. Thus, besides posting actionable information directed to the victims, organizations should post more information targeting potential donors and volunteers.

### 4 - Predicting Drug Recalls using Social Media Data

Hyunwoo Park, The Ohio State University, 2100 Neil Ave, 632  
Fisher Hall, Columbus, OH, 43210, United States, George Ball,  
Hessam Bavafa, Christian Blanco

Pharmaceutical quality is a topic of chief concern, and regulators are tasked with reviewing data on an ongoing basis so they can issue recalls when problems are identified. Given the potential harms at stake, there is great interest in improving the algorithms by which quality issues are identified. In our paper, we use a big data approach using text analysis of social media data to predict drug quality risks, i.e., the likelihood of drug recalls. Our approach leverages sentiment analysis combined with reviewer characteristics to show how social media data can aid quality management.

### 5 - Scalability of Follower Bases on Social Media Platforms for Humanitarian Operations

Eunae Yoo, University of Tennessee, Knoxville, TN, United States,  
Elliot Rabinovich, Bin Gu

For humanitarian organizations, increasing the scale of their follower bases on social media platforms is important to efficiently distribute information. With more followers, organizations can directly reach more users and communicate with a larger audience. Our study evaluates the drivers of the expansion of humanitarian organizations' follower bases in times of normalcy and emergency. We formulate a structural model to examine when users decide to follow an organization and estimate the model using Twitter data from before and after a recent earthquake. Among our results, we find that the type of content and the frequency of content release affect users' decisions to follow humanitarians.

## ■ MC11

North Bldg 125B

### Joint Session MSOM/Practice Curated: Empirical Studies in Operations

Sponsored: Manufacturing & Service Oper Mgmt/IFORM

Sponsored Session

Chair: William Schmidt, Cornell University, Ithaca, NY, 14850, United States

#### 1 - Supply Networks: Does Industry Matter

Manpreet Singh Hora, Georgia Institute of Technology, Scheller  
College of Business, 800 West Peachtree Steet NW, Atlanta, GA,  
30308, United States, Marcus Bellamy, Soumen Ghosh

We demonstrate differences in supply networks of focal firms in three different industries. In this study, we highlight the extent to which the industry context plays in terms of the network structural characteristics and firm performance, where the characteristics of an average representative firm in each industry vary considerably.

#### 2 - Global Supply Chains and Cross-border Financing

Jing Wu, City University of Hong Kong, Department of  
Management Sciences, Rm 7-233, Lau Ming Wai Academic  
Building, Hong Kong, Hong Kong, Yu Zhang

Financial globalization is still far from complete four decades after the end of the Bretton Woods System largely due to transaction costs and informational frictions. In this study, we ask if global supply-chain relationships help firms access cross-border financing in the international capital markets. Comparing two firms that are otherwise similar, we observe the firm that has formed global supply-chain relationship(s) to have more cross-border financing after the supply chain formation. This result is supported empirically by all major financing vehicles, including stock cross-listing, bond issuance, bank loans, and M&A deals.

### 3 - Discrimination in Global Sourcing: Field Experiments on Alibaba

Ruomeng Cui, Emory University, 1935 Ridgmont Lane, Decatur,  
GA, 30033, United States, Jingyun Li, Meng Li, lili Yu

Past research has found discrimination in Business-to-Customer online marketplaces. However, there has been little study on suppliers' discrimination behavior on B2B platforms in the context of global sourcing. We investigate whether price and racial discrimination of suppliers against retailers exists in B2B marketplaces across countries. We conducted two field experiments on Alibaba.com, one of the largest global procurement platforms in the world. Further, we investigate the mechanism behind and explore negotiation tactics to mitigate discrimination.

### 4 - Demand Volatility in Supply Chain Networks

William Schmidt, Cornell University, 314 Sage Hall, Ithaca, NY,  
14850, United States, Nikolay Osadchiy, Jing Wu

Demand volatility can adversely impact the firm's ability to match its supply with its demand, resulting in higher operational costs. As demand propagates upstream in a supply chain, its volatility can be amplified due to the bullwhip effect. We empirically examine this phenomenon in the context of a supply chain network and shed light on how firms may strategically mitigate its consequences.

## ■ MC12

North Bldg 126A

### Analytics for Food Safety in Global Supply Chains

Sponsored: Manufacturing & Service Oper Mgmt

Sponsored Session

Chair: Yanchong Zheng, Massachusetts Institute of Technology,  
Cambridge, MA, 02139, United States

#### 1 - Contextualizing Food Safety in China with Respect to the Supply Chain

Nicholas J. Renegar, Massachusetts Institute of Technology,  
Cambridge, MA, 02139, United States

We consider the problem of food safety from the regulator's perspective. What risk drivers lead to adulteration in food, and how should regulators determine which companies to test? We hypothesize that thinking of companies in terms of the agricultural supply chain can help to 1) identify the risky layers in the supply chain, and 2) identify the risky companies. Working with a large database of food safety tests collected from the Chinese FDA websites, we find supporting evidence for how this approach can help regulators, and we also find evidence that this approach is not currently being used in creating regulatory policy.

#### 2 - Systemic Risk Management of Food Supply Chains

Qi Yang, Massachusetts Institute of Technology, Cambridge, MA,  
United States

Due to China's dispersed agricultural supply chain, regulatory agencies have complicated decisions with regard to the focus of their testing. Some examples include how to allocate resources, and how to coordinate between the various regulatory agencies. Using data collected on China FDA food safety tests, along with data describing the farms and wholesale markets in Zhejiang, we used supply chain analytics to explore these questions. Our work with this data has already yielded several insights to identify key risk drivers in the supply chain and to determine the optimal allocation of testing resources.

#### 3 - Governance and Quality Control in China

Yanchong Zheng, Massachusetts Institute of Technology, Sloan  
School of Management, 100 Main Street, E62-578, Cambridge,  
MA, 02139, United States, Yasheng Huang, Shujing Wang

We empirically study how China's governance strength is associated with food safety risks across different regions. We develop a set of multifaceted measures of city-level governance based on objective, factual data, as opposed to basing on perceptual data in the most widely used governance indicators in social sciences. We leverage a unique dataset of domestic food sampling conducted by national-, provincial-, and city-level food regulators in China to examine the association. Our results highlight the different channels through which governance impacts food safety risks at a granular level.

#### 4 - Food Insecurity Analytics: Improving Chronic Disease Control via Food Pantries in USA

Luffina Huang, Georgia Institute of Technology, Atlanta, GA,  
United States, Mario Wijaya, Keith Woh, I. Tang Lo

This paper explored an unprecedented insight into the way of connecting food insecurity with the prevalence of two chronic diseases, obesity and diabetes, in U.S. via machine learning algorithms and data visualization geographically. While food banks are striving against food insecurity, large numbers of people in need cannot benefit due to improper ingredients in donated food for chronic-diseases patients. This paper showed food pantries provided limited help in control of food insecurity with chronic disease factors, and the most critical, proposed novel views in improving this problem.

## ■ MC13

North Bldg 126B

### Healthcare Operations II

Sponsored: Manufacturing & Service Oper Mgmt/Healthcare Operations

Sponsored Session

Chair: Susan F. Lu, Purdue University, West Lafayette, IN, 47907, United States

#### 1 - Managing with Targets in Healthcare: The Case of 4-hour Emergency Department Target

Basak Bebitoglu, London Business School, London, United Kingdom, Nicos Savva, Tolga Tezcan

The UK government has instigated a rule in 2010 where 95% of the patients should be seen, admitted or discharged within four hours in emergency departments. This caused a large proportion of patients (15.69%) to be processed in the last 20 minutes to the target. Therefore, this paper intends to understand the unintended consequences of this arbitrary 4-hour target with the final intention of creating a queuing model to generate counterfactuals. We fit Cox proportional hazards model using patient level data from over half million visits at a UK hospital emergency department. The results indicate that as the target gets closer, it creates a speed-up effect on patient treatment times.

#### 2 - Unintended Consequences of Hospital Regulation: The Case of the Hospital Readmissions Reduction Program

Christopher J. Chen, London Business School, Regent's Park, London, NW14SA, United Kingdom, Nicos Savva

We study the impact of the Hospital Readmissions Reduction Program on admissions decisions. Exploiting variation in hospitals' financial exposure to the program, we show that hospitals tried to reduce readmission rates by increasing the number of patients that were classified as admitted for "observation, which avoided potential penalties associated with a regular admissions.

#### 3 - Distance, Quality or Relationship? Inter-hospital Transfer of Heart Attack Patients

Susan F. Lu, Purdue University, Krannert 441, West Lafayette, IN, 47907, United States, Lauren Xiaoyuan Lu

We empirically investigate the pattern of where heart attack patients are transferred between hospitals. Using 2011 Florida State Emergency Department and Inpatient Databases, we demonstrate the relative importance of three key factors in determining transfer destinations: hospital relationship, distance, and quality. Our conditional logit analysis shows that the relationship of being affiliated with the same multihospital system plays a dominant role in the choice of transfer destinations, compared to distance and quality.

#### 4 - Dynamic Appointment Scheduling of Base and Surge Capacity

Benjamin Grant, Kellogg School of Management, 1881 Oak Avenue, # 1307W, Evanston, IL, 60201, United States

We study dynamic stochastic appointment scheduling when delaying appointments increases the risk of incurring costly failures, such as readmissions in health care or engine failures in preventative maintenance. When near-term base appointment capacity is full, the scheduler faces a trade-off between delaying an appointment at the risk of costly failures versus the additional cost of scheduling the appointment sooner using surge capacity.

## ■ MC14

North Bldg 126C

### Economic Models in Service Environment

Sponsored: Manufacturing & Service Oper Mgmt/Service Operations

Sponsored Session

Chair: Noam Shamir, Tel Aviv University, Tel Aviv, 49504, Israel

#### 1 - Worker Flexibility Training and Production Autonomy

Evan Barlow, Weber State University, Goddard School of Business & Economics, 1337 Edvalson St, Ogden, UT, 84408, United States, Gad Allon, Achal Bassambo

We explore the interaction between worker production autonomy and workers' decisions on training to become flexible resources. Research on flexible resources is prevalent in the operations management literature. Human resources, however, are decision makers and have rights to decide on their own skill sets. Many firms have given workers some production autonomy to choose how to use the skills they possess. We show how workers' training decisions are affected by the identity of the production and training decision makers.

#### 2 - Sample Boxes for Retail Products: Bundling Experience Goods to Leverage Consumer Uncertainty

Alireza Yazdani, University of Oregon, Eugene, OR, United States, Eren Basar Cil, Michael Pangburn

Consumers often try a few varieties of an experience product before they establish their shopping routine. Sample boxes create value through helping consumers resolve their valuation uncertainties of these varieties earlier and at a lower cost. In this paper, we study how firms and consumers share this added value under different market scenarios. We show that when a firm offers a sample box, consumers obtain higher net expected surplus while the firm's expected profit may decrease. We find that the firm can reverse the adverse effects of selling sample boxes by introducing an optimally specified future-credit.

#### 3 - Economics of Autonomous Vehicles: Formulation and Analysis of Optimal Policies

Mehdi Nourinejad, University of Toronto, Toronto, ON, L4B4G6, Canada, Opher Baron, Oded Berman

Autonomous vehicles are predicted to enter the consumer market in less than a decade. However, there is no consensus on whether their presence will have a positive impact on users and society. The skeptics of automation foresee increased congestion, whereas the advocates envision smoother traffic with shorter travel times. In this paper, we study the automation controversy using supply-demand analysis. We show that a sound judgment of automation relies on the occurrence of three possible cases for which full, null, or partial automation is recommended. Moreover, although traffic increases with automation, the travel times may decrease in certain cases.

#### 4 - Pricing Strategy and Collusion in a Market with Delay Sensitivity

Noam Shamir, Tel Aviv University, Haim Levanon, Tel Aviv, 49504, Liron Navner

In this paper, we study price collusion between two firms providing service to delay-sensitive customers using a discounted repeated game. The equilibrium is fully characterized along with specific conditions for the minimal discount factor that enables collusion. The effect of service value on the firm's revenue and ability to collude is further analyzed.

## ■ MC15

North Bldg 127A

### Consideration Sets in Choice Modeling

Sponsored: Manufacturing & Service Oper Mgmt/Service Operations

Sponsored Session

Chair: Gustavo J. Vulcano, Universidad Torcuato di Tella, Buenos Aires, 1428, Argentina

#### 1 - Estimation and Assortment Optimization for a Random Consideration Set Model

Anran Li, the Hong Kong University of Science and Technology, Department of IEDA, Room 5568, The HKUST, Mudd 345, Sai Kung, NY, 10027, Hong Kong

Manzini and Mariotti (2014) propose a consideration set based choice model that postulates a full preference ordering as well as exogenous attention probabilities from which consideration sets are formed. The model assumes that consumers select the highest ranked product in their consideration set and the heterogeneity among choices are due to randomness in the consideration sets formation process. While Manzini and Mariotti focus on rationalizing this choice model, we look at its operations applicability by looking into the parameter estimation and assortment optimization problems.

#### 2 - Inferring Competition Sets from Sales Transactions Data

Dmitry Mitrofanov, Stern School of Business, NYU, 44 West 4th Street, 8th Floor, New York, NY, 10012, United States, Gustavo J. Vulcano, Srikanth Jagabathula

We study the General Consideration Set (GCS) choice model to infer competition sets from sales transactions data. The primary question we address is whether the GCS model is identifiable. We provide necessary and sufficient conditions to assess if the sales data was generated by the model, and provide the arguments of how to infer the preference order and the probability distribution function over consideration sets from the observed choice frequencies. Our empirical results show that GCS choice model provides a very competitive choice prediction performance in comparison with state-of-the-art benchmarks, while providing the insights about competition sets.

#### 3 - Consumer Choice Models with Consideration Set

Ruxian Wang, Johns Hopkins University, Carey Business School, 100 International Dr, Baltimore, MD, 21202, United States

We study the two stage consider-then-choose model under which a consumer first forms her consideration set and chooses one within it. We investigate the operations management problems and develop efficient algorithms to estimate the new choice model.

#### 4 - Near-optimal Ranking and Display Algorithms under Multinomial Logit Preferences

Mohammed Ali Aouad, London Business School, London, United Kingdom

We study the display optimization problem, that seeks to compute an optimal ranking over distinct items (ads, products, etc.) that are displayed to a heterogeneous audience. Each customer considers a subset of the items assigned to the most favorable locations, before picking one alternative through Multinomial Logit choice probabilities. Our main contribution is to derive a polynomial-time approximation scheme for the display optimization model, thereby improving on the best-known constant-factor approximation. We develop an approximate dynamic programming formulation based on a surprisingly compact state space representation of assignment decisions.

### ■ MC16

North Bldg 127B

#### Socially Responsible Operations

Sponsored: Manufacturing & Service Oper Mgmt/Sustainable Operations

Sponsored Session

Chair: Leon Valdes, University of Pittsburgh, Pittsburgh, PA, 15260, United States

#### 1 - Job Design and Work Allocation for Volunteers in Nonprofit Organizations

Deishin Lee, Boston College, 140 Commonwealth Ave., Fulton Hall 344, Chestnut Hill, MA, 02467, United States, Joy Field, Tingliang Huang

The intent of this study is to understand how operational processes can be designed and managed to accommodate and leverage the distinct characteristics of non-profit organizations to maximize their performance. We first construct an analytical model and then use data from food banks to test the findings of our model.

#### 2 - Curtailing the Improper Waste Disposal: Evidence from California and Florida

Suvrat Dhanorkar, Pennsylvania State University, 466 Business Building, University Park, PA, 16802, United States, Suresh Muthulingam

We exploit the development of electronic waste legislation and related infrastructure to study the impact on waste in the electronic industry. We find evidence for the presence of a virtuous cycle where there is lower electronic waste disposal, curb in electronic related manufacturing waste, and reduction of electronic consumption. Our results point out the essential factors that curtail the improper disposal of waste.

#### 3 - Supply Risk Mitigation via Supplier Diversification and Improvement: An Experimental Evaluation

Basak Kalkanci, Georgia Institute of Technology, Atlanta, GA, 30339, United States

Firms are increasingly exposed to risks stemming from their suppliers such as health/safety violations or supplier failures. We use lab experiments to evaluate two sourcing strategies developed for supplier risk mitigation: dual sourcing and single sourcing with supplier improvement. With dual sourcing, human buyers do not diversify orders effectively and exhibit quantity hedging behavior. We propose and empirically validate a theory of order allocation error minimization to explain this phenomenon. In contrast, human buyers use supplier improvement relatively successfully, despite being subject to supplier selection errors.

#### 4 - Sustainable or Not? Role of Valuation Uncertainty and Operational Flexibility in Product Line Design

Weiqing Zhang, Washington University in St. Louis, One Brookings Drive, Saint Louis, MO, 63130, United States, Lingxiu Dong, Iva Petrova Rashkova

The purpose of the paper aims at exploring a big food company's optimal strategy structures when selling products incorporated with both sustainable and conventional quality dimensions to a market that has heterogeneous segments. By taking the features such as coupled cost structure, operational flexibility and consumer's volatile preferences into consideration, we find out the interplay of cannibalization and product upgrade effect determines the company's optimal strategies. Further, interesting implications such as wastes and consumer welfare can be explained.

### ■ MC17

North Bldg 127C

#### Information Management in Supply Chains

Sponsored: Manufacturing & Service Oper Mgmt/Supply Chain

Sponsored Session

Chair: Shilu Tong, The Chinese University of Hong Kong, Shenzhen, 2001, Long Xiang Blvg, CUHK Shenzhen, Shenzhen, 518172, China

#### 1 - Sharing Manufacturer's Demand Information under Linear Wholesale Price

Yunjie Wang, Renmin University of China, Zhongguancun Street, Beijing, 100080, China, Albert Y. Ha, Shilu Tong

We study the incentive for a manufacturer to share private demand information with two retailers who compete on price and service effort under a linear wholesale price contract. Without information sharing, the wholesale price may be distorted upward or downward due to a signaling effect. Information sharing allows the manufacturer to alleviate the signaling effect and influence downstream competition. We derive conditions under which the manufacturer shares information with none, one or both of the retailers. We also conduct sensitivity analysis to investigate the impact of some parametric changes on the information sharing equilibrium outcome as well as the firms' profits.

#### 2 - Incentives for Information Transparency under Vertical Information Asymmetry

Hongyan Xu, Chongqing University, School of Economics & Business Admin, Chongqing, 400030, China, He Huang, De Liu, Sammi Yu Tang

This paper studies the incentives for horizontal information transparency between competing downstream firms when upstream suppliers possess private information. Our findings enrich the understanding of horizontal information sharing under vertical information asymmetry and provide novel insights for managers to handle two-dimensional information asymmetry.

#### 3 - Quality Score Information Sharing in Reverse Auctions

Hedayat Alibeiki, California State University San Marcos, San Marcos, CA, United States, Mehmet Gumus

In this paper, we focus on the buyer-determined (price-plus format) reverse auctions, where the buyers use quality scores (QS) to evaluate their suppliers in terms of the non-price attributes. Analyzing the informational and strategic effects of QS in a reverse auction setting, we evaluate whether or not it is beneficial for the buyer to share relative QS information with the suppliers.

#### 4 - Information Sharing, Pricing Timing and Platform Selection

Yulan Wang, Hong Kong Polytechnic University, Department of Logistics and Maritime Studies, Faculty of Business, Kowloon, Hong Kong, Yanli Tang, Baozhuang Niu

In this study, we explore the information sharing decisions of two platforms, and the supplier's platform selection decision by studying a four-stage game under two pricing timing scenarios. We show that it is never in the best interest of the supplier to direct sell on the hybrid platform under the late pricing, whereas under the early pricing, the supplier may prefer direct selling on the hybrid platform; and the chosen platform shares its information with the supplier voluntarily. Interestingly, the supplier direct selling on the agency platform may benefit the hybrid platform under the late pricing. Moreover, the pricing timing preference of the supplier and the hybrid platform may be aligned.

### ■ MC18

North Bldg 128A

#### Academic Job Search Panel

Emerging Topic: INFORMS Career Center

Emerging Topic Session

Chair: Warren Hearn, Cardlytics, 4061 Water Oak Terrace SW, Lilburn, GA, 30047-7417, United States

#### 1 - Academic Job Search Panel

Warren Hearn, Cardlytics, 4061 Water Oak Terrace SW, Lilburn, GA, 30047-7417, United States

This panel discusses the academic interview process and do's and don'ts associated with the job search. In addition to comments by current and former search chairs, time will be provided for questions and answers.



## ■ MC19

North Bldg 128B

### Revenue Management in Uncertain Environments

Sponsored: Revenue Management & Pricing

Sponsored Session

Chair: Omar Besbes, Columbia University, New York, NY, 10027, United States

#### 1 - Personalized Dynamic Pricing with Machine Learning

N. Bora Keskin, Duke University, Fuqua School of Business, 100 Fuqua Drive, Durham, NC, 27708-0120, United States, Gah-Yi Ban

Motivated by online retail applications, we consider a seller who offers personalized prices to individual customers. The seller initially does not know the impact of individual customer characteristics on demand, but can learn about this relationship via sales observations. We construct and analyze near-optimal policies that balance the learn-and-earn tradeoff in this setting.

#### 2 - Stein Shrinkage for Stochastic Optimization

Vishal Gupta, USC Marshall School of Business, 3670 Trousdale Parkway, Los Angeles, CA, 90026, United States, Nathan Gahlin

Inspired by Stein's phenomenon in statistics, we propose a new shrinkage algorithm for solving many data-driven stochastic optimization problems simultaneously. Our procedure pools data across problems. Perhaps surprisingly, as the number of problems increases, our method outperforms methods that decouple the problems, even when the problems are unrelated and data are drawn independently. Unlike the Stein phenomenon in statistics, our method does not require strong distributional assumptions and applies to general constrained optimization problems.

#### 3 - Less Can Be More in Price Experimentation; The Uncertain Demand Case

Divya Singhvi, MIT, 516 University Avenue, Ithaca, NY, 14850, United States, Georgia Perakis

We consider a dynamic pricing problem where the retailer has no knowledge of the demand curve and there is a cost on price experimentation. The retailer seeks to efficiently learn the demand curve and keep the cost of price experimentation low. We propose an optimistic-pessimistic approach for price experimenting and learning which is simple and mimics industry practice. We provide bounds on the number of price experiments needed to achieve a threshold revenue level. We show that with few price experiments (aka 4) we can be within 18% of the optimal unknown price.

#### 4 - Prior-independent Optimal Auctions

Amine Allouah, Columbia University, New York, NY, 10027, United States, Omar Besbes

In this work, we study the design of optimal prior-independent selling mechanisms. In particular, the seller faces buyers whose values are drawn from an unknown distribution, and only knows that the distribution belongs to a particular class of distributions. We analyze a maximin setting in which the seller attempts to optimize the worst-case fraction of revenues compared to those of an oracle with knowledge of the distribution. We first characterize the structure of optimal mechanisms. Leveraging such structure, we then establish tight lower and upper bounds on performance, leading to a crisp characterization of optimal performance for a spectrum of families of distributions.

## ■ MC20

North Bldg 129A

### Joint Session RMP/Practice Curated: Marketplace Analytics

Sponsored: Revenue Management & Pricing

Sponsored Session

Chair: Wedad Elmaghraby

Co-Chair: Chris Parker, Pennsylvania State University, University Park, PA

#### 1 - Should I Pay for this Purchase or Redeem Points? Effects of Loyalty Program Design on Consumer Decisions to Redeem Points

So Yeon Chun, Georgetown University, Arlington, VA, 22202-7416, United States, Rebecca Hamilton

In many loyalty programs, customers earn points for their purchases, which they can later exchange for additional products and services. In a sense, points function as a currency that consumers can spend instead of money. However, we uncover systematic differences in the way consumers spend points compared with money. We first propose a conceptual model of the consumer's choice to redeem points or use money for a specific purchase, and then we conduct a series of studies to investigate the impact of program design characteristics on consumers'

choices. By linking the design characteristics to specific mechanisms, we provide insight into how program managers can influence consumers' decision.

#### 2 - How do Price Promotions Affect Customer Behavior on Retailing Platforms? Evidence from a Large Randomized Experiment on Alibaba

Dennis Zhang, Washington University in St. Louis, University City, MO, 63124, United States, Hengchen Dai, Lingxiu Dong

We study how a promotion strategy—offering customers a discount for products in their shopping cart—affects customer behavior in the short and long term on a retailing platform. We conducted a randomized field experiment involving more than 100 million customers and 11,000 retailers with Alibaba Group, the world's largest retailing platform. We randomly assigned eligible customers to either receive promotions for products in their shopping cart or not. In the short term, our promotion program doubled the sales of promoted products. In the long term, we causally document unintended consequences of this promotion program during the month following our treatment period.

#### 3 - Underrepresented Minorities and LGBT in the Sharing Economy: Bias and Financial Incentives in Ridesharing Platforms

Christopher Dalton Parker, Pennsylvania State University, 411 Business Building, University Park, PA, 16802, United States, Jorge Mejia

Operational transparency can be good for business. However, it may also enable biased behavior if those with information about customers can choose not to provide a service for the customer. We explore this through a field experiment on a major ridesharing platform which recently changed the timing of information provided to drivers in order to reduce bias. We find significant bias still exists against URM and LGBT individuals. However, dynamic pricing moderates the effects. Policy implications will be discussed.

#### 4 - Clearing Matching Markets Efficiently: Informative Signals and Match Recommendations

Yash Kanoria, Columbia Business School, 404 Uris Hall, New York, NY, 10027, United States, Itai Ashlagi, Peng Shi, Mark Braverman

We study how to reduce congestion in two-sided matching markets with private preferences. We measure congestion by the number of bits of information that agents must (i) learn about their own preferences, and (ii) communicate with others, before obtaining their final match. Previous results by Segal (2007) and Gonczarowski et al. (2015) suggest that a high level of congestion is inevitable under arbitrary preferences before the market can clear with a stable matching. We show that when the unobservable component of agent preferences satisfies certain natural assumptions, it is possible to recommend potential matches and encourage informative signals such that the market reaches a stable matching with a low level of congestion. The main idea is to only recommend partners with whom the agent has a non-negligible chance of both liking and being liked by.

## ■ MC21

North Bldg 129B

### Game Theory and Networks

Sponsored: Revenue Management & Pricing

Sponsored Session

Chair: Francesca Parise, MIT, Cambridge, MA, 02141, United States

Co-Chair: Asuman Ozdaglar, Massachusetts Institute of Technology, Cambridge, MA, 02139, United States

#### 1 - Path to Stochastic Stability: Comparative Analysis of Stochastic Learning Dynamics in Games

Hassan Jaleel, KAUST, Jeddah, Saudi Arabia, Jeff S. Shamma

Stochastic stability (SS) analysis can accurately explain the long-term behavior of stochastic learning dynamics. However, this solution concept does not explain the transient behavior of these dynamics. Consequently, we cannot distinguish between different learning rules with the same steady state using SS analysis. We develop a framework for the comparative analysis of stochastic learning dynamics with different update rules that lead to a same steady-state behavior. We propose multiple criteria to quantify the differences in the short and medium-run behaviors of these dynamics. We apply these criteria to compare Log-Linear Learning and Metropolis Learning and gain valuable insights.

#### 2 - A Variational Inequality Framework for Network Games: Existence, Uniqueness, Convergence and Sensitivity Analysis

Francesca Parise, Massachusetts Institute of Technology, Cambridge, MA, United States, Asuman Ozdaglar

We provide a unified variational inequality framework for the study of fundamental properties of the Nash equilibrium in network games. We identify several conditions on the underlying network (in terms of spectral norm, infinity norm and minimum eigenvalue of its adjacency matrix) that guarantee existence, uniqueness, convergence and continuity of equilibrium in general network games with multidimensional and possibly constrained strategy sets. We delineate the relations between these conditions and characterize classes of networks that satisfy each of these conditions.

### 3 - Online Platform Designs under Networked Cournot Competition

John Pang, California Institute of Technology, Pasadena, CA,  
United States, Weixuan Lin, Eilyan Bitar, Adam Wierman

We analyze designs of networked Cournot platform markets, considering (i) open access platform with transparent interactions to all participants, (ii) controlled allocation platform distributing aggregate productions efficiently, and (iii) discriminatory access platform allowing efficient interactions. We show that open access retains 2/3 of the optimal social welfare under anarchy while a controlled allocation platform optimizing social welfare can lead to anticipatory curtailment of production and inefficiency. Lastly, designing the network can lead to a 3/4 rate of optimal social welfare. We also introduce search cost, revealing the potential realistic inefficiency of open access.

### 4 - A Supply Chain Network Game Theory Model of Cybersecurity Investments with Nonlinear Budget Constraints

Anna B. Nagurney, University of Massachusetts Amherst, Isenberg School of Management, Dept of Operations & Information Mgmt, Amherst, MA, 01003, United States, Patrizia Daniele, Shivani Shukla

In this paper, we develop a supply chain network game theory model consisting of retailers and demand markets with retailers competing noncooperatively in order to maximize their expected profits by determining their optimal product transactions as well as cybersecurity investments subject to nonlinear budget constraints that include the cybersecurity investment cost functions. We provide alternative variational inequality formulations of the governing Nash equilibrium conditions, conduct Lagrange analysis, and apply the proposed algorithm to compute solutions to a spectrum of numerical supply chain network cybersecurity investment examples.

### 5 - Social Learning in a Dynamic Environment

Nir Hak, Harvard University, Cambridge, MA, 02138,  
United States, Krishna Dasaratha, Benjamin Golub

Agents learn about a moving state using private signals and past actions of their neighbors in a network. Can learning keep up with the changing environment? If private signals are sufficiently diverse and degrees sufficiently large, then Bayesian learning does very well, but not otherwise. Non-Bayesian learning rules do much worse, in contrast to environments with a fixed state. Stationary equilibria of Bayesian learning are characterized by linear rules reminiscent of the simple DeGroot heuristic. The resulting tractability can facilitate structural estimation of equilibrium learning models and testing against behavioral alternatives, as well as the analysis of welfare and influence.

## ■ MC22

North Bldg 130

### Strategic Environments and Incomplete Information

Sponsored: Revenue Management & Pricing

Sponsored Session

Chair: Yonatan Gur, Stanford University, Stanford, CA, 94305, United States

Co-Chair: Daniela Saban, Stanford, New York, NY, 10027, United States

### 1 - Procurement in a Strategic Environment

Gregory Macnamara, Stanford University, Stanford, CA,  
United States, Daniela Saban, Yonatan Gur

We study a dynamic game of incomplete information that models the interactions between a Principal ("Buyer"), who demands the same good or service repeatedly over time, and an Agent ("Seller"), who has private information. We characterize the effect that the strategic environment has on the Buyer's ability to learn.

### 2 - Manufacturer Encroachment in a Non-exclusive Reselling Channel

Parshuram Sambhajirao Hotkar, Doctoral Student,  
University of Texas at Austin, Austin, TX, 78751, United States,  
Stephen M. Gilbert

We consider the implications of a manufacturer operating a direct channel to encroach upon the market of a non-exclusive reseller. Although non-exclusive resellers are common in practice, most existing studies of encroachment ignore the possibility of competing manufacturers selling through the same reseller. As we show, the presence of competing manufacturers has dramatic implications for how / when a direct channel should be used and who benefits from it.

### 3 - Team Decision Making in Operations Management

Jiawei Li, PhD Candidate, Stephen M. Ross School of Business,  
701 Tappan St, Ann Arbor, MI, 48109, United States,  
Stephen Leider, Damian Beil

Existing behavioral OM literature has primarily studied individual decision makers. However, the behavioral economics literature suggests that teams may make better decisions in tactical settings, and may be more strategic and self-interested. We conduct a laboratory experiment and find that teams actually

perform worse than individuals when making Newsvendor decisions, exhibiting a stronger pull-to-center bias. In an information sharing game teams are less trustworthy when sharing information, but just as trusting when receiving information. Chat analyses are used to study the team decision-making process.

### 4 - Learning to Rank an Assortment of Products

Shreyas Sekar, Harvard University, Cambridge, MA, United States,  
Kris Ferreira

We consider the product ranking challenge that online retailers face when their customers typically do not have a good idea of the product assortment offered. These customers form an impression of the assortment after looking only at products ranked in the initial positions, and then decide whether they want to continue browsing all products or leave the site. We propose an online algorithm that learns consumer preferences and converges to the optimal full-information ranking.

## ■ MC23

North Bldg 131A

### Financial Services Award Session

Sponsored: Finance

Sponsored Session

Chair: Agostino Capponi, Columbia University, 500 W 120th street,  
New York, NY, 10027, United States

### 1 - Addressing Systemic Risk Using Contingent Convertible Debt – A Network Analysis

Lu Yueliang, UNC Charlotte, Charlotte, NC, USA.

We construct a balance sheet based network model to study the interconnectedness of US banking system. After a simulation analysis of the buffer effect of contingent convertible (CoCo) debt in controlling contagion in the banking network under a theoretically motivated model, we use 13-F filings made to the US Securities and Exchange Commission (SED) to calibrate the theoretical model. While CoCo debt with dual-trigger is not so efficient as a single trigger design in reducing individual bank failures, the former is more effective at protecting the surviving banks, which leads to improved stability from the perspective of the banking system. We claim that the different designs of CoCo triggers result in trade-offs for addressing systemic risk, which may be evaluated in a network model.

### 2 - Beating the Curse of Dimensionality in Options Pricing and Optimal Stopping

Yilun Chen, David Goldberg, Cornell University, Ithaca, NY, USA.

The fundamental problem of pricing high-dimensional path-dependent options is central to applied probability and financial engineering, yet has remained open for the better part of a century. Modern approaches, often relying on approximate dynamic programming and/or the martingale duality theory for optimal stopping, either have limited rigorous performance guarantees, or have guarantees which scale poorly and/or require previous knowledge of good basis functions. A key difficulty is that many approaches rely on computing nested conditional expectations, where the depth of nesting scales with the time horizon.

### 3 - Demand-Side Story of the Great Recession

Marco Zhang, The University of Chicago Booth School of Business,  
Chicago, IL, USA.

Using novel data on private pension plans' investment allocations and returns, we find that the skewed interest for pension fund managers led to the increased investments in Mortgage-Backed Security (MBS) in the years preceding the Great Recession, especially for large pension plans with actuarial value over \$10 billion. Such pension plans control much more investments per plan (they only represent less than 6% in our data but their aggregated investments is about 50% more than the remaining 94% combined) and are more likely to be under-funded (almost 64% of these plans are under-funded, compared to about 6% under-funded for the remaining plans). The skewed interest, together with the size of the investments the fund managers control, created both the will and the ability to dominate the MBS market. We find in our data that US private pension funds alone, which generally are much smaller compared to US public pension plans, put over \$1 trillion in MBS-related investments in 2007 when the entire MBS market was about \$9 trillion. The significant demand from the pension plans shifted the demand curve in the mortgage securitization market during the years prior to the Great Recession, which is supported by our observation of the concurrent increase of the quantity and the relative price for the MBS during the period. While there exists plenty literature studying the causes of the Great Recession from the supply-side, we are among the first to investigate and provide evidence of the roles pension plans played from the demand-side that contributed to the Great Recession.

#### 4 - Algorithmic Trading with Partial Information: A Mean Field Game Approach

Philippe Casgrain, Sevastian Jaimungal, University of Toronto, Toronto, ON, Canada.

Financial markets are often driven by latent factors which traders cannot observe. Here, we address an algorithmic trading problem with collections of heterogeneous agents who aim to perform statistical arbitrage, where all agents filter the latent states of the world, and their trading actions have permanent and temporary price impact. This leads to a large stochastic game with heterogeneous agents. We solve the stochastic game by investigating its mean-field game (MFG) limit, with sub-populations of heterogeneous agents, and, using a convex analysis approach, we show that the solution is characterized by a vector-valued forward-backward stochastic differential equation (FBSDE). We demonstrate that the FBSDE admits a unique solution, obtain it in closed-form, and characterize the optimal behaviour of the agents in the MFG equilibrium. Moreover, we prove the MFG equilibrium provides an  $\epsilon$ -Nash equilibrium for the finite player game. We conclude by illustrating the behaviour of agents using the optimal MFG strategy through simulated examples.

#### 5 - Dynamic Mean-Risk Asset Allocation and Myopic Strategies: A Universal Portfolio Rule

Zhaoli Jiang, The Chinese University of Hong Kong, Hong Kong, China, Xue Dong He

In a market that consists of multiple stocks and one risk-free asset whose expected return rates and volatility are deterministic, we study a continuous-time mean-risk portfolio selection problem in which an agent is subject to a constraint that the expectation of her terminal wealth must exceed a target and minimizes the risk of her investment, which can be the variance or tail risk of her terminal wealth. Setting the target to be proportion to the agent's current wealth, we derive the equilibrium policy in closed form, and this policy is myopic and does not depend on the risk measure used by the agent nor on the agent's evaluation period. For another two targets, one that is the risk-free payoff of the agent's current wealth plus a premium and the other that is a weighted average of the risk-free payoff of the agent's current wealth and a pre-determined target, we also derive the equilibrium policy in closed form when the agent measures risk by the variance of her terminal wealth.

### ■ MC24

North Bldg 131B

#### E-Business

Sponsored: EBusiness

Sponsored Session

Chair: Varun Gupta, Penn State Erie, The Behrend College, Erie, PA, 16563, United States

#### 1 - Role of Trust in Peer-to-peer Sharing Economy

Jagan Jacob, University of Rochester, Simon Business School, 4-349 Carol Simon Hall, Rochester, NY, 14627, United States

In online-based sharing-economy platforms such as Airbnb and Uber, trust between users is critical. If there are some "bad users who are discourteous with improper behavior, some risk-averse users may leave the platform. Stricter screening and entry requirements can reduce the probability of "bad users entering the platform. But, it also negatively affects the entry decisions of "good users, because of high entry-costs. How easy should it be for new users to sign-up to use the platform? What degree of background checking and screening procedure should the platform employ? I try to answer these questions using population dynamics models used in Ecology.

#### 2 - Multiproduct Dynamic Upgrades

Xiao Zhang, The University of Texas at Dallas, 800 W. Campbell Rd., SM 30, Richardson, TX, 75080, United States, Metin Cakanyildirim, Ozalp Ozer

Upgrades in travel industry are often static and offered either at the booking time or at the check-in time. In this paper, we study dynamically-offered upgrades by a multi-product firm via notifications (e.g., emails) between the booking and the check-in times. We investigate a general multi-level upgrade policy in which a customer may be upgraded to any better products and a restrictive single-level upgrade policy which is less computationally intensive. Both policies have clean structures and are easy to implement. We also identify intuitive monotonicity properties for the optimal single-level upgrade policy.

#### 3 - Demand Throttling for Bandwidth Preservation

Varun Gupta, Penn State-Erie, The Behrend College, 5101 Jordan Rd, Burke 281, Erie, PA, 16563, United States, Sandun Perera

Demand throttling is a commonly observed phenomenon for online service providers, who maintain their demand below a certain threshold to avoid any potential server crashes and to preserve their bandwidth. Using a generalized demand model based on Brownian motion, we analytically show that the optimal throttling policy resembles the  $(s,S)$  policy which is a well-known and commonly used inventory policy. Next, we provide numerical analysis and comparative statics of the analytical results. Finally, we discuss the managerial insights for bandwidth throttling policies in practice for online service providers.

#### 4 - Online Order Fulfillment with Central and Local Warehouses when Facing Strategic Customers

Chao Liang, Cheung Kong Graduate School of Business, Main Campus, Oriental Plaza 2/F, Tower E2, 1 East Chang An Ave., Beijing, 100738, China, Yuxin Chen

The e-tailer faces the problem of where to and how to allocate the inventory. If it keeps the inventory in suburban area (and thus far away from the customers), then it can enjoy a low warehouse renting cost but the shipping cost would be high. If it puts the inventory close to the customers, then it can save the shipping cost but the warehouse renting cost would be high. Another option is to keep inventory in both local and remote places. We study the e-tailer's inventory allocation decision when customers are strategic.

### ■ MC25

North Bldg 131C

#### Best Student Paper Competition - Session I

Sponsored: Service Science

Sponsored Session

Chair: Aly Megahed, IBM Research - Almaden, San Jose, CA, 95123, United States

#### 1 - Service Science Best Student Paper Competition

Aly Megahed, IBM Research - Almaden, San Jose, CA, 95123, United States

This session consists of finalists presentations (judged by an expert panel) to determine the Best Student Paper Award for the Service Science Cluster.

### ■ MC26

North Bldg 132A

#### Service Consumer

Sponsored: Service Science

Sponsored Session

Chair: Caner Canyakmaz, Ko University, Engineering Faculty, ENG 218, Istanbul / Sariyer, 34450, Turkey

#### 1 - Tier Pricing Optimization the Revolving Fund Problem

Ruben A. Proano, Associate Professor, Rochester Institute of Technology, Kate Gleason College of Engineering, 81 Lomb Memorial Drive, Rochester, NY, 14623, United States, Galo Eduardo Mosquera

We use a three-stage optimization process to study alternative configurations of the Pan-American Health Organization Revolving Fund (RF), which is a single-tier group procurement mechanism used to buy vaccines for countries in the Americas. We propose an innovative approach to determine willingness-to-pay among vaccine buyers, and study the optimal number of tier prices that maximize affordability and profit, and the potential impact of large countries in the continent procuring vaccines independently.

#### 2 - Two-dimensional Extended Warranties for Price-sensitive Customers

Amitava Mitra, Professor, Auburn University, College of Business, Lower Building Suite 419, Auburn, AL, 36849-5266, United States

Products, such as, automobiles, have warranty policies that incorporate two dimensions, namely time since purchase of the product and usage based on accumulated mileage. While an initial warranty is offered during purchase of the product, options exist to renew the warranty in the event of no failure during the initial warranty. Here we consider extended warranty policies where the propensity to extend the warranty is influenced by the product price, relative to a threshold value. The decision variables include the warranty time and usage limit in the original and extended policies, the product price, and the premium to be charged for extending the warranty.

#### 3 - Improving Affordability in a Coordinated Non-cooperative Vaccine Market through Configuration of Group Buying Membership

Bruno Alves Maciel, Rochester Institute of Technology, 59-6 Colony Manor Drive, Rochester, NY, 14623, United States, Ruben Proano, Galo Eduardo Mosquera

We discuss the effect of allocating different countries into multiple vaccine purchasing groups whose procurement decisions are optimized by coordinating entities. These entities maximize savings for group members while offering profitability to vaccine producers. The vaccine purchasing groups form a hypothetical non-cooperative coordinated vaccine market. Coordinating entities choose their procurement plans via a two-stage optimization problem optimizing procurement decisions and pricing strategies. This study quantifies how group composition affects optimal procurement policies that incentivize higher affordability and profit in the vaccine market.



#### 4 - Service Systems with Rationally Inattentive Customers

Caner Canyakmaz, Postdoctoral Researcher, ESMT European School of Management and Technology, Schlossplatz 1, Berlin, 10178, Germany, Tamer Boyaci

Many service systems are partially visible such that customers are not always able to discern precise queue lengths upon arrival. This stems mainly from potential information frictions due to environment and/or cognitive capabilities of customers. We analyze rational queueing behavior under limited customer attention through rational inattention framework. Customers optimize their information acquisition process trading-off the benefits of better information against its cost. We characterize equilibrium strategies and investigate the effect of information cost on throughput and social revenue.

## ■ MC27

North Bldg 132B

### Student Attitudes Towards Learning OR/MS/Analytics

Sponsored: Education (INFORMED)

Sponsored Session

Chair: Susan Wright Palocsay, James Madison University, Harrisonburg, VA, 22807, United States

#### 1 - Moderator

Susan Wright Palocsay, James Madison University, Msc 0202, Computer Info Sys & Bus Analytics Dept, Harrisonburg, VA, 22807, United States

Analytics is providing new opportunities to create business value. Consequently, coverage of quantitative analysis/modeling skills has increasing importance in undergraduate education. The panel will discuss the role of students' attitudes in learning OR/MS/Analytics.

#### Panelists

Natalie M. Scala, Towson University, Dept. of e-Business and Technology Management, 8000 York Road, Towson, MD, 21252, United States

#### 1 - Academic Motivation in Introductory Business Analytics Courses

Baback Vaziri, James Madison University, 2210 Reserve Circle, Unit 203, Harrisonburg, VA, 22801, United States, Stacey Kelly, Elham Torabi, Luis J. Novoa

The purpose of this study is to examine relationships among student perceptions of their learning experience, including levels of motivation and effort, and their performance in introductory business analytics courses using the MUSIC Model of Motivation. The results from this study will be used to identify research-based motivation strategies that can be used to improve instruction and suggest techniques to improve student learning experiences. Specifically: 1) students' rating of model components, 2) strategies to improve model component scores, and 3) predictive or explanatory trends in model component scores with effort and performance.

## ■ MC28

North Bldg 221A

### Train Design and Service Planning

Sponsored: Railway Applications

Sponsored Session

Chair: Seyed Mohamad Nourbakhsh, BNSF

#### 1 - Simulating Railcar Transit under Different Operating Strategies

Tzu-Yu Chang, University of Illinois at Urbana Champaign, Urbana, IL, United States, Darkhan Mussanov

This research investigates how railway classification yard operating strategies and train schedule flexibility affect the average railcar transit time across a network. Simulation results suggest that, for all the three operating strategies studied, transit time increases as the level of schedule flexibility increases. Depending on the specific traffic and blocking scenario, different operating strategies result in the shortest average railcar transit time. The resulting trends may help railway practitioners in formulating more robust train and yard operating plans.

#### 2 - An Integrated Train Service Plan Optimization Model with Variable Demand

Xuesong Zhou, Arizona State University, Tempe, AZ, United States, Lingyun Meng

A well designed train timetable should fully utilize the limited resources to maximize operators' profits and passenger travel demand satisfaction. This talk explains an integrated demand/service/resource optimization model for managing the above-mentioned three key decision elements. By using a Lagrangian relaxation solution framework to recognize the dual costs of both passenger travel demand and limited resources of track and rolling stock, we decompose the formulation into a novel team-based train service search sub-problem for

maximizing the profit of operators. Numerical experiments are conducted to examine the effectiveness of the dual and primal solution search algorithms.

#### 3 - Optimization Models for Block Re-design Problem

Chinmoy Mohapatra, BNSF Railways, Arlington, TX, United States, Anantaram Balakrishnan

Railroads develop blocking plans to consolidate shipments into groups (or blocks) at intermediate yards so as to minimize the total handling costs and transit miles of all shipments. We model the blocking problem as a network design problem with maximum degree and node flow constraints, and consider restrictions based on material types. We discuss modeling and algorithmic enhancements to effectively solve this large-scale integer program, and present computational results for actual problem instances.

#### 4 - Trade-off Between Efficiency and Equity under Time Dependent Passenger Demand in Railway Timetabling

Dewei Li, Beijing Jiaotong University, Beijing, China, Tianyu Zhang, Xinlei Dong

The aim of this paper is to analyze and to improve the efficiency and transportation equity of urban railway timetable. A MIP model is proposed in which the train operation constraints and train capacity constraints are taken into account, an adaptive large neighbor algorithm is designed to solve this problem. The feasibility of the model and algorithm is verified by the Changing line of Beijing Metro. A sensitivity analysis on the weight of efficiency and equity in objective function illustrates that different weight can cause different result in the aspect equity and efficiency.

#### 5 - Visualizing the Effects of Maintenance on Train and Yard Performance

Trefor Williams, Rutgers University, Piscataway, NJ, United States, John F. Betak

Using actual data from a railroad in the United States, graph network visualizations have been constructed to better understand the linkages between the location of maintenance activities such as rail replacement and surfacing with delays to through freights and missed switching deliveries to customers. This analysis also includes the use of text mining to identify typical maintenance problems, major problems and accident locations from the railroads maintenance records. We will demonstrate how these visualizations can be used to identify critical areas in the railroad's track network where delays are frequently caused by maintenance activities.

## ■ MC29

North Bldg 221B

### Innovations in Last-Mile Urban Package Delivery

Sponsored: TSL/Urban Transportation

Sponsored Session

Chair: Bo Zou, University of Illinois, IL, 60607, United State

#### 1 - Same-day Delivery Using In-store Customer with Store Transfers

Alp Arslan, Rotterdam School of Management, Pannekoekstraat 58C, Rotterdam, 3011LJ, Netherlands, Niels Agatz

This paper considers a system in which in-store customers can make deliveries on their way to home. They may deliver directly to the home of an online customer or transfer the package at another store after which another in-store customer makes the final delivery. To examine the potential of such store transfers, we present an optimization approach to match delivery tasks and in-store customers in real-time.

#### 2 - Integrated Modeling of Crowdsourced Urban Delivery with Rebalancing Consideration

Bo Zou, University of Illinois, 2073 Engineering Research Facility, 842 W. Taylor Street, Chicago, IL, 60607, United States

This research investigates using crowdsourcing for urban delivery. We focus on a specific type of crowdsourcing that deals with delivering shipments from spatially distributed locations such as restaurants, and retail, grocery, and drug stores to customers who are also spatially distributed, within a guaranteed time. We consider not only assigning shipments dynamically to compatible crowdsources to allow for time-guaranteed delivery, but also strategically repositioning crowdsources at the same time so that crowdsourcing supply can be better matched spatially with shipment demands.

#### 3 - Designing Electronic Marketplaces for Transportation Services

Arim Park, Rutgers University, Newark, NJ, 07102, United States, Yao Zhao, Soohyun Cho, Seongtae Kim

On-demand matching services for commercial transportation needs have only recently entered the market in South Korea, with early players like Uber Freight and Convoy seeking new ways to solve inefficiencies in the transportation sector. With this in mind, we would like to design an efficient mechanism for facilitating the growth of an electronic market of transportation services (trucking) in Korea. To this end, we would first conduct empirical studies to identify the preferences of both customers and carriers (truckload freight carriers). We provide meaningful guidance in the matching process between shippers and carriers in e-marketplace.

#### 4 - A Last Mile Delivery Paradigm using Microhubs with Crowdshipping

Jane Lin, University of Illinois-Chicago, 842 W. Taylor Street (M/C 246), Chicago, IL, 60607, United States, Sudheer Ballare

This study investigates the feasibility of a delivery paradigm in microhubs with crowdshipping. Performance was evaluated by comparing with the traditional Hub-and-Spoke paradigm in terms of vehicle miles traveled, numbers of trucks and crowdshippers dispatched, fuel consumption, and total daily operating cost. The study also investigates the effect of key operational parameters such as network size, customer demand density, crowdshipper payment and penalty rate on the performance of M+C. It is found that M+C generally outperforms H+C with the economy of scale. It is also found that higher penalty rate increases the attractiveness of the proposed M+C delivery paradigm.

#### 5 - Uncertainty at Scale: The Technician Routing Problem with Hard Time-Windows, Time-Dependent Travel, and Stochastic Service Times

Ishai Menache, Microsoft, Cambridge, MA, United States

We revisit the VRP for field services. Our goal is to account for inherent uncertainty in work-duration or travel-time. To that end, we introduce risk as an additional measure. Risk quantifies the probability of “bad outcomes in the schedule; for example, missing a work-order time-window. We design efficient algorithms for estimating the risk. Based on that, we design and evaluate a scalable optimization framework, which allows operators to choose the sweet point of risk vs. expected performance, akin to portfolio management.

### ■ MC30

North Bldg 221C

#### Recent Advances in Facility Location and Supply Chain Design

Sponsored: TSL/Facility Logistics

Sponsored Session

Chair: Lian Qi, Rutgers University, Piscataway, NJ, 08854, United States

#### 1 - Two-stage Stochastic Programming of Facility Location Problem with Endogenous Uncertainty

Mengnan Chen, University of Central Florida, Orlando, FL, United States, Qipeng Zheng

Our study aims to improve hospital efficiency by allocating the hospital resource (physician and clinic), as well as matching the patient preference to maximize the patients' satisfaction. We use the two-stage stochastic programming to model the physician/clinic facility location and patient assignment problem, where the patient preference is considered as the endogenous uncertainty. To solve this model, we design the hybrid heuristic algorithm, that the Tabu Search (TS) and Large Neighborhood Search (LNS) are used to solve the facility location problem, and Sample Average Approximation (SAA) is used to handle the exponential increasing scenario size of patient assignment problem.

#### 2 - On Retail Chain Store Location Decisions

Dincer Konur, Missouri University of Science and Technology, 206 Emse, 600 W. 14th Street, Rolla, MO, 65401, United States

This paper studies store location decisions of a retail chain. The located stores will be competing for the demand in the end consumer market. The retail chain can prefer centralized or decentralized approach for determining the store locations. In the case of decentralized approach, the stores will engage in a competitive facility location game. We analyze the location decisions under each approach. Numerical studies are conducted to demonstrate the effects of different approaches and parameters on the outcome of the store location decisions.

#### 3 - Product Geographical Distribution under Recall Risk

Ying Rong, Shanghai Jiao Tong University, No. 1 Lane 9, Yunwushan Road, Shanghai, 200051, China, Long He, Zuo-Jun Max Shen

When product recalls happen, companies not only have to incur additional logistics costs but also suffer from damaged reputation. In this paper, we discuss how to alleviate the consequences of product recalls in the perspective of (outbound) product geographical distribution strategy in joint with (inbound) sourcing decision.

#### 4 - Locating Distribution Centers in a Collaborative Logistics Network

Chase Rainwater, University of Arkansas, 4207 Bell Engineering Center, Fayetteville, AR, 72701, United States

Researchers worldwide have concluded that meeting a shift towards smaller, fast-moving, unit loads calls for a new paradigm for future logistics systems. A potential cornerstone of a proposed new paradigm is collaboration and, in particular, horizontal collaboration. The vision embraces advancing technologies and is consistent with the issues challenges addressed by Industry 4.0. This talk focuses specifically on the design of a collaborative supply chain network as it relates to the location of shared distribution centers and warehouse. The impact of horizontal collaboration on the design choices made to construct such network are specifically discussed.

### ■ MC31

North Bldg 222A

#### New Mobility Services

Sponsored: TSL/Intelligent Transportation Systems (ITS)

Sponsored Session

Chair: Roksana Asadi, Stony Brook University, 100 Nicolls Rd, Stony Brook, NY, 11794, United States

#### 1 - Ridesharing and Self-parking with Autonomous Vehicles:

##### A Novel Multimodal Ridesharing and Parking User Equilibrium

Bo Zou, Assistant Professor, University of Illinois at Chicago, 2073 Engineering Research Facility, 842 W. Taylor Street, Chicago, IL, 60607, United States, Mohamadhossein Noruzoliaee

This study explores the impacts of Autonomous Vehicles (AVs) on transportation system equilibrium focusing on ridesharing with shared AVs and self-parking with private AVs. A Stackelberg game is developed where a profit-maximizing Transportation Network Company (TNC) chooses shared AV fleet size, sets fare rates, and decides on fleet allocation/relocation. The associated system equilibrium is formulated as a novel Multimodal Ridesharing and Parking User Equilibrium (MRPUE) problem, which determines market share of AV in a mixed autonomous/human driving environment.

#### 2 - User and System Optimal Matching for Dynamic Ride Sharing Systems

Pramesh Kumar, University of Minnesota, Minneapolis, MN, 55414, United States, Alireza Khani

This research develops an optimization model for matching riders with drivers in a ride sharing problem with dynamic travel times. The objective is to reduce travel delay and schedule deviation, and multiple rider matching is allowed. In addition to the system optimal model, a user optimal model is presented in which users cannot improve their match unilaterally.

#### 3 - A Modeling Framework for the Integrated Vehicle-drone Routing Problem

Aline Karak, PhD Student, Southern Methodist University, Amesbury, Dallas, TX, 75206, United States, Khaled Abdelghany

We present a mathematical formulation for the integrated vehicle-drone routing problem in the context of pick-up and delivery services. An efficient heuristic-based solution methodology that captures the cost trade-off and operational characteristics of the two modes is presented. The methodology introduces a multi modal version of the classical Clarke and Wright algorithm. The results of a set of experiments are presented, which compare the solution performance against drone-driven and vehicle-driven solutions.

#### 4 - Joint Optimization of Electric Power Distribution and Electric Vehicle Charging Infrastructure Design under Network Traffic Equilibrium

Roksana Asadi, Graduate Student, Stony brook university, 100 Nicolls Rd, Stony Brook, NY, 11794, United States, Leila Hajibabai

This study investigates an integrated plan for the power distribution network (PDN) design and electric vehicle (EV) charging station deployment in urban transportation networks with the underlying traffic flows. The problem is characterized by a bi-level model structure with PDN design and facility location decisions in the upper level and traffic equilibrium in the lower level. The objective is to minimize the total cost due to PDN operation, charging facility deployment, and transportation. The problem is converted into a single-level model based on the Karush-Kuhn-Tucker conditions and solved using a column and constraint generation algorithm.

## ■ MC32

North Bldg 222B

**Intermodal Transportation and Ports**

Sponsored: TSL/Freight Transportation &amp; Logistics

Sponsored Session

Chair: Rob A. Zuidwijk, Erasmus University-Rotterdam, 3000 DR, Netherlands

**1 - Transportation Network Resilience, Supply Chain Resilience and Economic Impacts**

John F. Betak, Managing Member, Collaborative Solutions LLC, Dept. of Information, Risk &amp; Operations Mgmt, McCombs School of Business, The University of Texas-Austin, David R. Fletcher

We discuss relationships between supply chain approaches to resiliency, risk management and public sector activities involving risk-based transportation asset management and resilience management by: 1) public sector infrastructure decisions impacting certain supply chain systems and networks, including military materiel supply chains; and 2) incorporating specific reliability and resilience requirements of these supply chains into public investment decision-making processes. We show how the interconnected decisions impact international Intermodal container movements in the supply chain. Alternative modeling approaches are explored and research recommendations are offered.

**2 - A Comprehensive Overview of Hinterland Transport as a System of Interacting Actors: A Supply Chain Perspective**

Volkan Gumuskaya, PhD Candidate, Eindhoven University of Technology, Eindhoven, Netherlands, Willem van Jaarsveld, Remco Dijkman, Albert Veenstra, Paul Grefen

Hinterland transport is the total of import and export activities between a port and its hinterland, involving physical and planning processes, which are characterized by the interaction of actors and the contractual relationships. In practice, the actors act according to their own goals resulting in coordination issues and system wide inefficiencies. These inefficiencies emerge in the form of a lack of information exchange and a lack of collaboration leading to operational problems. To address these problems and enhance future research directions, we create a comprehensive overview of the hinterland transport focusing on the interaction of the actors and identify the coordination issues.

**3 - Enhancing Resilience through Port Collaboration in Maritime Freight Networks**

Wenjie Li, George Mason University, Fairfax, VA, 22030, United States, Ali Asadabadi, Elise Miller-Hooks

Reliable port services are key to the performance of maritime freight transport systems that are vulnerable to disaster events of anthropogenic or natural cause. Strategies involving capacity expansion and protective cross-port investments, as well as collaborations that enable capacity sharing between ports, are proposed. These strategies aim to reduce the impact of such disruptive events on goods movements through maritime freight transport networks. This collaborative port protection and investment problem is formulated as a bi-level program with multiple players (leaders) in the upper level and a common liner shipping problem (the followers) in the lower level.

**4 - Planning of Heterogeneous Capacity in Intermodal Networks with Uncertain Demand**

Hobbs White, Erasmus University Rotterdam, Rotterdam, Netherlands, Bart Wiegman, Rob A. Zuidwijk

Faced with uncertain demand, an intermodal network operator must source transportation capacity from a pool of carriers and service providers, heterogeneous in characteristics such as mode and availability. The operator will seek to hedge against the risks of inefficient asset utilization and costly recourse by selecting optimally from a set of potential agreements with capacity suppliers, given ranges of duration, lead-time, and levels of purchase commitment. To support interpretation, we extend the formulation of this network design problem as a minimum cost stochastic program by studying an analytically tractable approach centered on a multidimensional newsvendor model.

**5 - A Parametric Analysis of Collaborative Hinterland Container Transport**

Alberto Giudici, Erasmus University Rotterdam, Rotterdam, Netherlands, Tao Lu, Clemens Thielen, Rob A. Zuidwijk

Evidence from practice shows that the goal of improving service quality of port-to-door container transport can motivate operators to cooperate. Once cost savings are generated by sharing orders or transport capacity, companies will selfishly bargain for the cost allocation. Following Nash Program, we consider the Shapley value as the resulting non-cooperative cost allocation and test its coalition rationality. Basing the cooperative game on a parametric min-cost flow problem, we analytically study the dependency of the Shapley value and core on penalty costs for late deliveries. Our results show that when the amount of orders shared is close to the total capacity pooled, cooperation is stable.

## ■ MC33

North Bldg 222C

**Joint Session ORAM/QSR/Practice Curated: Advancements in Spatial Data Analytics Methods for Manufacturing Quality Control**

Emerging Topic: OR and Advanced Manufacturing

Emerging Topic Session

Chair: Mohammed Shafae, University of Arizona, Tucson, AZ, 24061, United States

Co-Chair: Wenmeng Tian, Mississippi State University, Mississippi State, MS, 39762, United States

**1 - Spatial Statistics and Scan Statistics for SPC: A Comparison**

Romina Dastoorian, Western Michigan University, Kalamazoo, MI, 49009, United States, Lee Wells

Modern manufacturing systems contain numerous high-density spatial data-sets that are obtained from advanced measurement technologies. Statistical Process Control (SPC) techniques that have been developed for these data-sets can be separated into two primary categories, namely spatial statistics and scan statistics. Unfortunately, the performances of proposed SPC techniques developed within these two areas are rarely (if ever) been compared. In response, this work presents a fair and balanced simulation-based performance comparison between several spatial statistics and scan statistics SPC approaches across a variety of process shift scenarios for image data.

**2 - Layer-wise Anomaly Detection for Spatially-correlated Thermal Images in Laser-based Additive Manufacturing**

Ahmed Aziz Ezzat, Texas A&amp;M University, College Station, TX, United States

We propose a layer-wise anomaly detection method for laser-based additive manufacturing as a step towards enabling real-time process control. Using in-process thermal images, process anomalies are signaled through a multi-step data-driven procedure that includes segmentation, spatial modeling, and classification analysis. We validate the proposed method using a case study on a commercial laser powder bed fusion system instrumented with a dual-wavelength imaging pyrometer for capturing the thermal signature during fabrication.

**3 - Scene Understanding and Obstacle Detection for Off-road Autonomous Driving Based on Real-time LiDAR Sensing**

Wenmeng Tian, Mississippi State University, P.O. Box 9542, Mississippi State, MS, 39762, United States

Scene understanding and autonomous navigation methodologies have been developing rapidly with the help of machine learning and artificial intelligence technologies. Moreover, advanced sensing techniques such as LiDAR systems can generate high volume of point cloud data for scene understanding. In this work, we propose a novel scene understanding and obstacle detection method based on a modified version of the Adaptive Generalized Likelihood Ratio (AGLR) method, originally proposed for surface inspection in manufacturing applications. A case study based on a LiDAR simulator is used to illustrate the effectiveness of the proposed approach.

**4 - Generalized Heterogeneous Recurrence Analysis of Spatial Data**

Cheng-Bang Chen, The Pennsylvania State University, State College, PA, 16801, United States, Hui Yang, Soundar Kumara

Prior research has shown that the heterogeneous recurrence method is effective in the characterization and quantification of heterogeneous recurrence behaviors in the temporal data. With the use of fractal representation, recurrence patterns are investigated in multiple scales. However, very little has been done to investigate heterogeneous recurrence behaviors in spatial data. This research extends the heterogeneous recurrence analysis to the high dimensional spatial data. We develop a novel structure to define the heterogeneous states, then provide a new fractal representation. Our method provides a novel platform for monitoring and control of dynamic recurrences of spatial data.



## ■ MC34

North Bldg 223

### 1:30 - 2:15 Lindo Systems, Inc/2:15- 3:00 FICO

Vendor Demo Session

#### 1 - Optimization Modeling Tools from LINDO Systems

Mark A. Wiley, LINDO Systems Inc, 1415 No Dayton Street, Chicago, IL, 60622, United States, Gautler Laude

Exceptional ease of use, wide range of capabilities, and flexibility have made LINDO software the tool of choice for thousands of Operations Research professionals across nearly every industry for over 30 years. LINDO offers solvers to cover all your optimization needs. The Linear Programming solvers handle million variable/constraint problems fast and reliably. The Quadratic/SOCP/Barrier solver efficiently handles quadratically constrained problems. The Integer solver works fast and reliably with LP, QP and NLP models. The Global NLP solver finds the guaranteed global optimum of nonconvex models. The Stochastic Programming solver has a full range of capabilities for planning under uncertainty. Get the tools you need to get up and running quickly. LINDO provides a set of intuitive interfaces to suit your modeling preference. What's Best! is an add-in to Excel that you can use to quickly build models that managers can use and understand. LINDO has a full featured modeling language for expressing complex models clearly and concisely, and it has links to Excel and databases that make data handling easy. LINDO API is a callable library that allows you to seamlessly embed the solvers into your own applications. Pick the best tool for the job based upon who will build the application, who will use it, and where the data reside. Technical support at LINDO is responsive and thorough - whether you have questions about the software or need some modeling advice. Get started today. Visit our booth or [www.lindo.com](http://www.lindo.com) to get more information and pick up full capacity evaluation licenses.

#### 2 - End-to-End FICO Register Xpress Insight Tutorial: From Data to Decisions for Non-Technical Business Users

James T. Williams, FICO, 2665 Long Lake Rd, Building C, Roseville, MN, 55113, United States

You have a team with a great analytics background. They have developed advanced analytical tools using Python, R, or with your current traditional optimization solver. They have derived crucial insights from your data, and they've figured out how your decisions shape your customers' behaviors. Now it's time to put these critical analytical insights in the hands of your non-technical business users. In this tutorial, we will cover how FICO's Optimization Suite (including Xpress Mosel, Xpress Workbench, and Xpress Insight) makes it possible to embed your analytic models in business user-friendly applications. Learn how you can supercharge your analytic models with simulation, optimization, reporting, what-if analysis, and agile extensibility for your ever-changing business.

## ■ MC35

North Bldg 224A

### AAS Best Student Presentation Competition III

Sponsored: Aviation Applications

Sponsored Session

Chair: Susan Hotle, Virginia Polytechnic Institute and State University

#### 1 - An Approximate Dynamic Programming Approach for Aircraft Maintenance Scheduling Optimization

Qichen Deng, Delft University of Technology, Kluyverweg 1, Delft, 2629 HS, Netherlands

We propose an approximate dynamic programming approach to optimize the maintenance check for a fleet of heterogeneous aircraft. It is the first time to optimize long-term aircraft maintenance schedule considering different check types (A-/C-/D-checks), merging different check types (A-check into C-check and D-check into C-check), maintenance intervals of different aircraft usage parameters (flight hours, cycles and calendar days) and uncertainty of maintenance elapsed time. The goal is to maximize aircraft availability, reduce maintenance costs, and minimize the unused flight hours of fleet in 3-5 year planning horizon and the decision variables are the start dates of each check.

#### 2 - A Variable Neighborhood Search Approach for the Flight-to-Gate Reassignment Problem

Moschoula Pternea, University of Maryland, College Park, MD, 20740, United States

The reallocation of flights to gates in case of schedule disruptions is a key airport recovery operation. Especially in hub airports, disruptions affect connecting passengers by causing failed connections or lost baggage. At the same time, introducing passenger transfers in mathematical programming models makes the problem intractable. In this context, we develop a Variable Neighborhood Search approach to generate near-optimal solutions with the objective to minimize

additional schedule disturbances, as well as passenger and baggage misconnections. Our preliminary experiments indicate that our metaheuristic approach shows promising results in terms of both solution quality and time.

#### 3 - Strategic Behaviors in Airport Capacity Allocation Mechanisms

Weilong Wang, Carnegie Mellon University, Pittsburgh, PA, United States

We develop an original bi-level game-theoretic approach to identify opportunities for strategic behaviors by non-atomistic users (e.g. airlines) in non-monetary mechanisms for infrastructure (e.g. airport) capacity allocation. We show that gaming opportunities are limited under a primary mechanism, where capacity is allocated to individual flights. In contrast, airlines may have strong gaming opportunities in a secondary mechanism, where capacity is allocated to airlines who may then swap their own flights. We present computational results comparing the overall performance of both mechanisms.

#### 4 - Investigating Autonomous Air Operations Centers for On-Demand Mobility Networks

Victoria Nneji, Duke University, Durham, NC, United States

On-Demand Mobility (ODM) in aviation has gained popularity in recent years, with several manufacturers proposing vehicles for air taxis. However, less attention has been placed on how the networked fleets would be managed. Through the development of concepts of operations for remote management of vehicles, this research presents preliminary requirements for ODM centers. This effort identified key requirements related to vehicle safety for these futuristic concepts. Further, this work introduces a model of human-system performance in these centers. With this tool, people making strategic decisions can prototype concepts of operations to better plan for staffing and design of the centers.

## ■ MC36

North Bldg 224B

### Airline Schedule Design

Sponsored: Aviation Applications

Sponsored Session

Chair: Keji Wei, Dartmouth College, Hanover, New Hampshire

#### 1 - Effects of Enterprise Bargaining and Agreement Clauses on Operating Cost of Airline Ground Crew Scheduling

Cheng-Lung Wu, UNSW Sydney, School of Aviation, Kensington, NSW 2052, Australia,, Shao Xuan Lim

Collective enterprise bargaining empowers airlines to negotiate labour conditions but it is not always clear how labour conditions affect costs. In this study, integer programming models are used to generate check-in staff rosters by considering individual roster conditions. Results showed that the shorter the shift length, the lower the rostering cost, saving around 30% by reducing shift length from 8 to 4 hours. With a ratio of 37% full-time staff in the workforce, there is a further 4.5% reduction in rostering cost. Cost saving can be redirected to employees as wage rises and improve job security.

#### 2 - Airline Timetable Development and Fleet Assignment Incorporating Passenger Choice

Keji Wei, Dartmouth College, Thayer School of Engineering at Dartmouth, 14 Engineering Dr., Hanover, NH, 03755, United States, Vikrant Vaze, Alexandre Jacquillat

We introduce an original integrated optimization approach to comprehensive timetabling and fleet assignment under endogenous passenger choice. An original multi-phase solution approach and several acceleration heuristics are proposed. Our solution approach significantly outperforms direct implementation using a commercial solver. Computational results using a major airline's network suggest that our overall modeling and computational approach results in significant profit improvements within a realistic computational budget. We present several extensions for strategic decision-making.

#### 3 - An Assessment of the Potential Benefits of Dynamic Airline Scheduling

Ahmet Esat Hızir, PhD Student, Massachusetts Institute of Technology, Cambridge, MA, United States, Vikrant Vaze, Cynthia Barnhart

The commonly used approach to airline schedule design does not enable airlines to effectively adapt to changes in passenger demand and airspace system capacity. This study investigates the potential benefits of a dynamic scheduling approach in which flight frequencies, schedules and aircraft types are finalized closer to the day of operations based on the most current demand information. Our integrated schedule design and fleet assignment model satisfies the passenger demand without inconveniencing passengers, to evaluate the maximum possible benefits of a dynamic scheduling strategy.

**4 - A New Strategic Airline Fleet and Pricing Optimization Model**

Xiaodong Luo, Sabre Holdings Inc, 3150 Sabre Drive, Southlake, TX, 76092, United States

We study a new integrated airline fleet assignment model when itinerary prices are also subject to change. Both fleet assignment models with complex passenger mix behavior as well pricing optimization models are well studied in the literature, but they are rarely studied simultaneously. We will use a combination of nonlinear optimization, heuristics and integer programming techniques to reduce computational time while still obtain close to optimal solutions. We will use discrete event simulation based on real airline data to demonstrate the power of our approach.

**MC37**

North Bldg 225A

**Joint Session APS/ENRE: Applied Probability and Power Systems**

Sponsored: Applied Probability

Sponsored Session

Chair: Bert Zwart, Eindhoven, 5629RD, Netherlands

Co-Chair: Foekje Sloothak, Eindhoven University of Technology, Eindhoven, 5612 AZ, Netherlands

**1 - Battery Swapping Stations for Electric Vehicles: A Queueing Perspective**

Foekje Sloothak, Eindhoven University of Technology, Den Dolech 2, Eindhoven, 5612 AZ, Netherlands

Although there has been an increasing penetration of EVs in the last decade, the adoption of this technology remains slow, partly due to issues with long battery charging times. We consider the concept of battery swapping stations where EV users can quickly exchange their (almost) depleted batteries by full batteries. We take a queueing perspective by modeling this framework as a closed system operating under the QED policy. This policy yields favorable effects: EV users experience low waiting times, while battery swapping stations do not needlessly keep many spare batteries. Moreover, we show state-space collapse when EV users are inclined to swap their batteries at the station that is least loaded.

**2 - Stochastic Networks for Electric Vehicle Charging**

Angelos Aveklouris, Eindhoven University of Technology, P.O. Box 513, Eindhoven, 5600 MB, Netherlands, Maria Vlasiov, Bert Zwart

We analyze a stochastic system that models the performance of electric vehicle charging. The model takes into account the stochastic behavior of electric vehicles and the physical constraints in a low-voltage distribution grid. We model this as a class of resource-sharing networks and characterize the performance of the system by a fluid approximation.

**3 - Chance-constrained AC Optimal Power Flow**

Line Roald, Assistant Professor, University of Wisconsin-Madison, 1645D 16th Street, Los Alamos, NM, 87544, United States

Renewable electricity generation increase uncertainty in power system operation and necessitates new methods for planning and operation. We adopt a chance-constrained AC optimal power flow formulation, which guarantees constraint satisfaction with a pre-defined probability. Obtaining solutions for this problem is challenging due to the AC power flow equations, a set of non-linear, non-convex equality constraints that must be satisfied with high probability. We discuss two different solution approaches based on partial linearization and polynomial chaos expansion, discuss their respective drawbacks and advantages, and show numerical results for different IEEE test cases.

**MC38**

North Bldg 225B

**APS Session Title VII**

Sponsored: Applied Probability

Sponsored Session

Chair: Bo Zhang

Co-Chair: Gauri Joshi, Carnegie Mellon University

**1 - Fast Distributed Machine Learning in the Presence of Slow and Stale Updates**

Gauri Joshi, Carnegie Mellon University, 5000 Forbes Avenue, Pittsburgh, PA, 15213, United States

Stochastic Gradient Descent when distributed across multiple nodes, suffers from delays due to slow or straggling nodes. Asynchronous methods can alleviate stragglers, but cause gradient staleness that can adversely affect convergence. We present a theoretical characterization of the speed-up offered by asynchronous methods by analyzing the trade-off between the error in the trained model and the wall-clock training runtime. Our runtime analysis considers random straggler

delays, which helps us design and compare distributed SGD algorithms that strike a balance between stragglers and staleness. We also present a novel learning rate schedule to compensate for gradient staleness.

**2 - Asynchronous Algorithms Faster Iterations Same Quality**

Robert Hannah, UCLA, Wotao Yin

In this talk, we discuss recent results on the performance of asynchronous optimization algorithms. Using renewal theory we analyze how subproblem and computing power heterogeneity, random delays, and other factors lead to asynchronous algorithms completing faster iterations. In particular, under a standard model, random delays lead to a slowdown by a factor of  $\ln(p)$ , when the number of computing nodes  $p$  is sufficiently large. We then present results that show that a number of asynchronous algorithms need essentially the same number of iterations as their traditional counterparts to converge to a solution. And hence we conclude asynchronous algorithms will dominate traditional ones at scale.

**3 - On the Loss Surface of Neural Networks for Binary Classification**

R Srikant, University of Illinois, Coord Science Lab & Dept of ECE, University of Illinois, Urbana, IL, 61801, United States

Deep neural networks used for classification problems are trained so that their parameters achieve a local minimum of an appropriate loss function. The loss function is typically intended to approximate the classification error in training samples. In this talk, we will show that approximations of widely-used neural network architectures have the property that every local minimum of a surrogate loss function is a global minimum, and further achieves the global minimum of the training error. Joint work with Shiyu Liang, Ruoyu Sun, and Jason Lee.

**MC39**

North Bldg 226A

**Networks, Reliability & Extremes**

Sponsored: Applied Probability

Sponsored Session

Chair: Pieere L'Ecuier, Universite de Montreal, C.P. 6128, Succ Centre-Ville, Montreal, QC, H3C 3J7, Canada

Co-Chair: Guido Lagos, Universidad de Chile, Santiago, 8370213, Chile

**1 - A Concentration Phenomenon for Network Reliability under Dependent Failures**

Guido Lagos, Universidad de Chile, Jose Miguel Carrera 439, depto 802, Santiago, 8370213, Chile

Guido Lagos, Universidad Adolfo Ibanez, Santiago, Chile, Javiera Barrera

We consider the reliability of a network where link failures are correlated, where we define the reliability at a given time instant as the probability of, at that time, there being at least  $k$  fixed links working. Our main contribution is a concentration result of a non-trivial scaling regime for the reliability of the network, as the time and size of network scales. Our results allow to study the common-cause failure models on networks in a realistic, relevant, yet practical, fashion: it allows to capture correlated components in the network; it allows to estimate and give error bounds for the failure probabilities of the system; and at same time only needs to specify a reduced family of parameters.

**2 - Efficient Monte Carlo Estimation of Network Reliability Metrics with the Standard Estimator**

Gerardo Rubino, INRIA, Campus de Beaulieu, Rennes, 35042, France

We consider the network reliability problem, in a static context. Estimating the system reliability using the standard or crude approach is a trivial task. It becomes a hard problem when dealing with a rare event situation (that is, when the system reliability is close to one), because the standard approach is quickly useless. In this presentation we will describe a way of using the standard estimator in an efficient way, in the case of rare events. One interest of this idea is that it allows, in a direct way, estimating all kinds of metrics without changing the method, and also to estimate sensitivities. The talk will be illustrated with some realistic examples of networks.

**3 - Large Deviations of Multivariate Gaussian Extrema**

Harsha Honnappa, Purdue University, 315 N. Grant Street, West Lafayette, IN, 47906, United States, Raghu Pasupathy, Prateek Jaiswal

We present a large deviations (LD) analysis of multivariate Gaussian extreme value random vectors. Our analysis contrasts with classic extreme value theory, which focuses on the 'nominal' behavior of extreme values. We demonstrate that the LD behavior of the multivariate Gaussian extremes is Frechet-like. Furthermore, we identify the "dominating point" at which the extreme values enter convex regions of interest in the range of the extreme value random vectors. Finally, we discuss applications of the LD results to reliability problems.

**4 - Designing Resilient Power System under Natural Hazards**

Tomas Ignacio Lagos, Universidad de Chile, 2017 - Pozuelo, Vitacura, Santiago, 7640031, Chile

We propose an assessment framework to measure the energy-not-supplied of the Chilean electricity grid conditional to high-impact-low-probability hazards events, such as earthquakes. Then, we use an Optimization via Simulation approach for designing the best investment set on the system in terms of resilience. The simulator contains historical earthquake data, fragility curves of the network components, and a unit commitment model. We compare the results with traditional reliability-based methods and prove that these do not provide resiliency to the system. Finally, we show approximation methods that allow to improve the robustness to deliver optimal solutions using the heuristic.

**■ MC40**

North Bldg 226B

**Decision Making Under Uncertainty**

Sponsored: Decision Analysis

Sponsored Session

Chair: Youngsoo Kim, PhD, University of Alabama, Tuscaloosa, AL, United States

**1 - An Interactive Bayesian Method for Multicriteria Sorting Problems**

Canan Ulu, Georgetown University, McDonough School of Business, Operations and Information Management Area, Washington, DC, 20057, United States

We present a method that interactively places alternatives into preference categories (e.g. most, somewhat and least preferred). We assume the decision maker has a linear value function and her responses are prone to error. In each step of the algorithm, we ask the decision maker to place an alternative in a category and using this information, we update our estimate of her value function via MCMC. We compare our method to other algorithms in the literature that assume away response errors.

**2 - The When and How of Delegated Search**

Sasa Zorc, INSEAD, 1 Ayer Rajah Avenue, PhD Office, Singapore, 138676, Singapore, Iliia Tsetlin, Sameer Hasija

We consider the decisions of whether and how to outsource a search process (e.g., headhunting, search for investment opportunities). We model it in the dynamic principal-agent framework. The optimal contract is shown to have a purchase rights structure: the agent is paid a retainer plus a bonus if the principal accepts the search outcome. The size of this bonus can be defined a priori and is decreasing in time. The decision of whether to outsource or no can be reduced to the principal's preferences over the quality-speed tradeoff, with quality preference leading to optimality of in-house search.

**3 - Dual Reoptimization based Approximate Dynamic Programming Policies**

Danial Mohseni-Taheri, College of Business, University of Illinois at Chicago, 601 S. Morgan St., Chicago, IL, 60607, United States, Selvaprabu Nadarajah, Alessio Trivella

Markov decisions processes (MDPs) with continuous endogenous and exogenous state and action spaces that are all high dimensional arise in operations applications. An example is the dynamic procurement of renewable power using multiple contracts under uncertain power prices and demand. The information relaxation and duality approach (IRD) can be used to obtain a lower bound on the optimal policy value of such MDPs, but approximate dynamic programming methods for computing operating policies are limited. We present a dual reoptimization method for extracting a feasible policy from IRD in this setting, guarantees on this policy, and numerical results on a renewable procurement application.

**4 - Strategic Investment in Shared Suppliers with Quality Deterioration**

Youngsoo Kim, University of Alabama, Tuscaloosa, AL, United States, Dharma Kwon, Anupam Agrawal

Firms often invest in their suppliers to improve their quality, but these suppliers are often shared by other firms who also consider investing in them. Motivated by this, we study a game of investment where one firm can free-ride on the other's investment. Facing a continued deterioration in the supplier's quality, each firm repeatedly decides when to invest in the supplier's quality. We find that the repetitive nature of the investment induces inefficient delays in investment. We then compare the inefficient equilibrium to the first-best and estimate the resulting efficiency loss by using primary data, concluding that coordination among the firms can potentially save substantial amount of money.

**5 - Protecting the Downside While Minding the Upside: Comparing Robustness Approaches in a Product Line Design Problem**

Tan Wang, University of Texas at Austin, Austin, TX, United States, Genaro J. Gutierrez

Robustness approaches are useful when decisions must be made before uncertainties resolve. Two major approaches to robustness are: 1) maximizing the value of the worst outcome and 2) minimizing the ex-post regret of the decision made. We examine performance tradeoffs between the two approaches in the product line design problem, and we construct an efficient frontier for robust designs obtained by both approaches. Our findings indicate that it is possible to find robust designs that mitigate downside risk while limiting ex-post opportunity losses.

**■ MC41**

North Bldg 226C

**Healthcare Decision Analysis**

Sponsored: Decision Analysis

Sponsored Session

Chair: Mehmet Ayyaci, University of Texas at Dallas, Richardson, TX, United States

Co-Chair: YeongIn Kim, University of Texas-Dallas, Richardson, TX, 75080, United States

**1 - Examining Impacts of Clinical Practice Variation on Operational Performance**

Seokjun Youn, Texas A&M University, 320M Wehner Building, 4217 Texas A&M University, College Station, TX, 77840-4217, United States, Gregory R. Heim, Subodha Kumar, Chelliah Sriskandarajah

Motivated by bundled payment policies that aim to reduce practice variation, this study examines whether and how lower variation in clinical practice relates to hospital operational performance. We further delve into the granular level of practice variation, such as the under-ordering risk of laboratory/radiology tests, to suggest actionable improvement plans. Using six-year inpatient data from NY and FL, we find that hospitals with higher practice variation tend to spend more resource for patient treatment. We also shed light on the intervening impacts of hospital quality evaluations on the relationship and deliver policy implications.

**2 - Determinants of Health Information Exchange Use on Different Stages of Postadoption**

Xiang Wan, University of Florida, Gainesville, FL, United States, Emre M. Demirezen, Anuj Kumar

The full potential of the benefits of health information exchanges (HIEs) cannot be realized until HIEs are used by physicians regularly. Few studies have focused on HIE postadoption phenomena and little is known about how different factors affect the continued HIE use. We empirically examine the effect of physician workload and disease complexity on HIE use at three different stages after physicians' first use: namely initial use, moderate use, and heavy use. We find that the relationship between physician workload (or disease complexity) and continued HIE use behavior depends on the specific stage the provider is at. Our contribution to the literature and practice is on several fronts.

**3 - Empowering Patients can Increase Digital Divide: The Effects of Patient Portals on Kidney Allocation**

YeongIn Kim, University of Texas-Dallas, Richardson, TX, 75080, United States, Mehmet Ayyaci, Srinivasan Raghunathan, Bekir Tanriover

The recent healthcare reform promotes the use of information technology, such as patient portals, to provide patients better access to information sources. Motivated by the kidney transplant decision, we empirically analyze the impact of the patient portals on outcomes including time to deceased-donor transplant. We show that, overall, the adoption of a patient portal is positively associated with the probability of receiving a deceased-donor kidney. However, the impact is less for minority groups who have limited access to transplant service, which may imply further service divide in kidney transplant.



## ■ MC42

North Bldg 227A

**Simulation Optimization in Networks**

Sponsored: Simulation

Sponsored Session

Chair: Kalyani Nagaraj, Oklahoma State

**1 - Rare-event Simulation for Electric Power Distribution Networks**

Chang-Han Rhee, Centrum Wiskunde and Informatica, Jakoba Mulderplein 164, Amsterdam, 1018 MZ, Netherlands, Bert Zwart, Nick Vasmel

We investigate a rare-event simulation problem for the electric power distribution network. We reformulate the non-linear problem described by the power flow equation into a simulation problem of a Markov chain. Building on this formulation, we propose variance reduction methods for the simulation estimation of voltage drop probability.

**2 - The Population Dynamics Algorithm**

Mariana Olvera-Cravioto, University of California, Berkeley, 4125 Etcheverry Hall, Berkeley, CA, 94720, United States

This talk will focus on the convergence of the population dynamics algorithm, which produces sample pools of random variables having a distribution that closely approximates that of the special endogenous solution to a variety of branching stochastic fixed-point equations often encountered in the analysis of random graphs. Specifically, we show its convergence in the Wasserstein metric of order  $p$  ( $p \geq 1$ ) and prove the consistency of estimators based on the sample pool produced by the algorithm.

**3 - Risk-averse Set Covering Problems**

Hao-Hsiang Wu, University of Washington, 5000 25th Avenue NE, Seattle, WA, 98105, United States, Simge Kucukyavuz

We consider probabilistic set covering problems under conditional value-at-risk. Suppose that we have an oracle that computes the risk efficiently for a given solution. Using this oracle, we propose methods for solving the risk-averse set covering problem exactly. We give valid inequalities that strengthen the formulation. We report our computational experience with the proposed methods on a probabilistic set covering problem that admits an efficient risk oracle.

## ■ MC43

North Bldg 227B

**Energy and Climate 8: Urban Energy Systems Modeling, Control, and Grid Interactions**

Emerging Topic: Energy and Climate

Emerging Topic Session

Chair: Thomas Deetjen, Carnegie Mellon University, Austin, TX, 78701, United States

**1 - Using Optimization to Identify Decarbonization Pathways for Cities and Districts**

Ashreeta Prasanna, Empa Swiss Federal Laboratories

Decarbonization of the energy supply system of a city is an extremely complex process. Planning for centralized and distributed energy provision over a longer time frame involves consideration of the objectives of several stakeholders, potential technology improvement over time, impact of local and national policy, and age of the existing building and technology stock. Using a case study, we show how all these aspects can be considered within a multi-stage optimization model to identify optimal pathways for decarbonization of a city.

**2 - Scout Software for National Building Energy Efficiency Impact Assessment**

Jared Langevin, Lawrence Berkeley National Laboratory

Scout is an open-source software program developed by the U.S. Department of Energy's Building Technologies Office (BTO) that estimates the energy, carbon, and operating cost impacts of energy conservation measures (ECMs) on U.S. residential and commercial buildings across both long- and short-term time horizons. In this work, Scout's core analysis capabilities are described, including building technology stock-and-flow dynamics and the adoption logic used to compete ECMs that apply to the same segments of baseline energy use. Recent extensions of Scout to time-sensitive valuations of energy efficiency are also discussed.

**3 - Smart Charging Management of Shared Autonomous Electric Vehicles and Implications for the Grid**

T. Donna Chen, Assistant Professor, University of Virginia, P.O. Box 400742, Charlottesville, VA, 22904, United States, Zhuoyi Zhang

As shared autonomous electric vehicle (SAEV) fleets roll out to the market, fleet charging will significantly impact energy demand. Existing EV smart charging (SC) research focus on privately-owned EVs (utilized for 5% of the day, on

average), but such strategies cannot apply to fleet managed SAEVs (continually in-service). This research proposes a SAEV SC framework to shift electricity demand away from peak use hours (price-based SC) or towards hours with high renewable generation (generation-based SC). A case study from Puget Sound region integrates the regional travel demand model, real-time energy prices, and regional renewable generation data.

**4 - Statistical Approaches to Large-scale Building Modeling and Grid Applications**

Eric Wilson, National Renewable Energy Laboratory, Golden, CO, United States

This presentation will provide an overview of the data sources and methodology behind ResStock, a highly granular bottom-up engineering model that represents national, regional, and local housing stocks using hundreds of thousands of sub-hourly building energy models. Several real-world applications of ResStock will be discussed, including how ResStock is being used by cities to answer their most pressing questions about electrification, resilience, and achieving 100% renewable energy goals.

## ■ MC44

North Bldg 227C

**Time-Varying Optimization and Learning in Power Systems**

Sponsored: Energy, Natural Res &amp; the Environment/Electricity

Sponsored Session

Chair: Steven Low, California Institute of Technology, Pasadena, CA, United States

Co-Chair: Yujie Tang, California Institute of Technology, Pasadena, CA, 91125, United States

**1 - Feedback-based Power System Optimization with Time-varying Constraints**

Adrian Robert Hauswirth, ETH Zurich, Physikstrasse 3, Zurich, 8055, Switzerland, Saverio Bolognani, Gabriela Hug, Florian Dörfler

We study continuous-time, non-smooth dynamical systems which arise in the context of time-varying non-convex optimization, as for example the feedback-based optimization of power systems. We generalize the notion of projected dynamical systems to time-varying domains and derive conditions for the existence of solutions. These requirements relate to the time-varying nature and constraint qualifications for the optimization problem as well as the structure of the feedback control. To illustrate the necessity and usefulness of such a framework, we consider a simple yet insightful power system example, and discuss the implications of the proposed conditions for feedback optimization schemes.

**2 - Asynchronous and Distributed Tracking of Time-varying Fixed Points**

Andrey Bernstein, Senior Scientist, National Renewable Energy Laboratory, Golden, CO, United States

We develop an algorithmic framework for tracking fixed points of time-varying contraction mappings. Analytical results for the tracking error are established for the cases where: (i) the underlying map changes at each step of the algorithm; (ii) only an imperfect information of the map is available; and, (iii) the algorithm is implemented in a distributed fashion, with communication delays and packet drops leading to asynchronous algorithmic updates. The analytical results are applicable to several classes of problems, including time-varying contraction mappings emerging from online and asynchronous implementations of gradient-based methods for time-varying convex programs.

**3 - An Optimal and Distributed Feedback Voltage Control under Limited Reactive Power**

Guannan Qu, Harvard University, 33 Oxford Street, Room 336, Cambridge, MA, 02138, United States, Na Li

In this talk, we propose a distributed voltage control in power distribution networks through reactive power compensation. The proposed control can (i) operate in a distributed fashion where each bus makes its decision based on local voltage measurements and communication with neighbors, (ii) always satisfy the reactive power capacity constraint, (iii) drive the voltage magnitude into an acceptable range, and (iv) minimize an operational cost. We will also present the underlying methodology behind the voltage control, a variant of primal-dual gradient algorithm (dynamics) that have geometric convergence rate (exponential stability) guarantee, which may be of independent interest.

#### 4 - Data-driven Voltage Control in Distribution Networks

Jiafan Yu, Stanford University, Stanford, CA, United States

Traditional approaches to reactive power management in distribution networks have focused on designing stable and near-optimal centralized or distributed control schemes under the assumption that network physics constraints are completely known. In this talk, we explore an alternative approach that learns a control procedure by observing streams of measurements from the system. We show that a simple batch learning and optimal control procedure attains comparable performance to existing approaches without requiring any prior knowledge of the network and give some analytical guarantees. We then show how the procedure can be utilized to construct an online learning process for the problem.

### ■ MC45

North Bldg 228A

#### Game Theory and Electricity Market

Sponsored: Energy, Natural Res & the Environment/Electricity

Sponsored Session

Chair: Luce Brotcorne, INRIA, Villeneuve D'Ascq, 59650, France

#### 1 - Unit Commitment under Market Equilibrium Constraints

Bernard Fortz, Université libre de Bruxelles, Brussels, Belgium,  
Luce Brotcorne, Fabio D'Andreagiovanni, Jérôme De Boeck

We consider an extension of the Unit Commitment problem with a second level of decisions ensuring that the produced quantities are cleared at market equilibrium. In their simplest form, market equilibrium constraints are equivalent to the first-order optimality conditions of a linear program. The UC in contrast is usually a mixed-integer nonlinear program (MINLP), that is linearized and solved with traditional Mixed Integer (linear) Programming (MIP) solvers. Taking a similar approach, we are faced to a bilevel optimization problem where the first level is a MIP and the second level linear.

#### 2 - A Bilevel Optimization Formulation of Priority Service Pricing

Anthony Papavasiliou, Université Catholique de Louvain, Center  
for Operations Research and Econometrie, Voie du Roman Pays 34,  
Louvain la Neuve, 1348, Belgium, Yuting Mou, Philippe Chevalier

Priority service pricing is a promising approach for mobilizing residential demand response, by offering electricity as a service with various levels of reliability. The proper pricing guarantees consumers self-select a level of reliability that corresponds to the reliability that the system can offer. However, traditional theory for menu design is based on numerous stringent assumptions. In addition, the objective of the menu design is to maximize social welfare, while the profit requirement is not accounted for. We design a priority service menu as the solution to a Stackelberg game modelled as a bi-level optimization problem. The approach is illustrated on the Belgian power market.

#### 3 - Increasing Electric Vehicle Adoption via Strategic Siting of Charging Station

Martim Joyce-Moniz, Polytechnique Montreal, Montreal, QC,  
Canada, Miguel Anjos, Bernard Gendron

Governments everywhere have started setting ambitious goals for electric vehicle (EV) adoption for the next few decades. One important obstacle to massive EV adoption, however, is the lack of a reliable, wide-reaching network of publicly-available charging stations that allows drivers to charge their EV both along their daily commutes and longer travels. We present a multi-period optimization framework for the siting and sizing of fast charging stations over large landscapes, which incorporates evidence-based demand dynamics reflecting how new infrastructure impacts EV adoption growth.

#### 4 - A Bilevel Framework for Optimal Price-Setting of Time-and-level-of-use Tariff

Miguel F. Anjos, Polytechnique Montreal, Montreal, QC, Canada,  
Mathieu Besançon, Luce Brotcorne, Juan A. Gomez-Herrera

The Time and Level of Use is an energy tariff for Demand Response, designed for residential users and providing suppliers with guarantee on the consumption. We formulate the supplier decision as a bilevel, biobjective problem optimizing for both financial loss and guarantee. A decomposition method is proposed, related to the epsilon-constraint and optimal value transformation. It allows for the computation of an exact solution by finding optimality candidates and then eliminating dominated ones. The method is effectively applied to experimental consumption data.

### ■ MC46

North Bldg 228B

#### Energy Markets II

Sponsored: Energy, Natural Res & the Environment/Energy

Sponsored Session

Chair: Seyedamirabbas Mousavian, Clarkson University, NY, 13699-5790, United States

Co-Chair: Felipe A. Feijoo, I

#### 1 - Deep Neural Network Ensemble Structures for Multi-step Forecasting of Ocean Wave Elevation and WEC Power Output

Mohammad Pirhooshayan, Lehigh University, Bethlehem, PA, 18015, United States, Lawrence V. Snyder

There exists an undeniable interest toward utilizing ocean energy as a renewable energy source. This research focuses on the Multiple step ahead prediction of ocean wave heights and power via innovative structure of Deep Neural Networks. An ensemble of Bidirectional Long short Term Memory (BLSTM) Networks is proposed to capture both long and short dependencies of the large historical data. Several optimization algorithms such as ADAM and RMSProp, SGD, etc., are considered to optimize the network. The results indicate that the proposed model is more accurate in compare with conventional forecasting methods such as Support Vector Regression (SVR) or SARIMA.

#### 2 - Green Investment under Policy Uncertainty and Bayesian Learning

Verena Hagspiel, Norwegian University of Science and Technology, Trondheim, Norway, Jacco J.J. Thijssen, Peder Dalby, Gisle Gillerhaugen, Tord Leth-Olsen

This paper examines how investment behavior is affected by updating a subjective belief on the timing of a subsidy revision. We analyze a scenario where a retroactive downward adjustment of fixed feed-in tariffs (FIT) is expected through a regime-switching model. We find that investors are less likely to invest when the arrival rate of a policy change increases, and prefer a lower FIT with a long expected lifespan. If electricity is sold in a free market after retraction we find that if policy uncertainty is high, an increase in the FIT will be less effective at accelerating investment. However, if policy risk is low, FIT schemes can significantly accelerate investment, even in highly volatile markets.

#### 3 - Quantifying the Effect of Natural Gas Price Uncertainty on Economic Dispatch Cost Uncertainty with Estimated Correlated Uncertainties

Dan Hu, Iowa State University, Ames, IA, 50010, United States, Sarah M. Ryan

In competitive electricity markets, vulnerability in gas supply to electricity generators creates a risk of high electricity prices. We propose a daily economic dispatch model that accounts for natural gas availability and cost from both contracts and the spot market. With probabilistic correlated inputs estimated from historical data for electricity demand and gas spot prices, we use Monte Carlo simulation to generate the resulting distributions of electricity dispatch cost both with and without gas price uncertainty. The effect of gas price uncertainty is assessed in terms of distance between the distributions and the effect of gas availability is addressed through sensitivity analysis.

#### 4 - Toward a Synthetic Model for Distribution System Restoration and Crew Dispatch

Bo Chen, Argonne National Laboratory, Lemont, IL, United States

Distribution service restoration (DSR) is critical for improving the resilience and reliability of modern distribution systems. Restoring electricity service to affected customers requires multiple crews with different skill sets to perform multiple tasks that are procedurally interdependent. We introduce a synthetic model that integrates both a service restoration model and crew dispatch model based on a universal routing model considering the switching sequence for safely operating remotely/manually operated switches, and dispatch solutions for crews with different skill sets.

## ■ MC47

North Bldg 229A

### A Guide to Optimization Based Multi-Period Planning

Emerging Topic Session

Chair: Esma S. Gel, Arizona State University, School of Computing, Informatics and, Decision Systems Engineering, Tempe, AZ, 85287-8809, United States

#### 1 - A Guide to Optimization Based Multi-Period Planning

Linus Schrage, LINDO Systems, Chicago, IL, 60637, United States

Many organizations use multi-period planning models that involve optimization to decide things like the best production or investment levels in multiple periods into the future. There are a wide variety of features a user would like to have in such models. How those features are represented affects both the usefulness of the results and the solvability of these models as you add more periods to the model, or add more products, or in general, increase the detail. This tutorial describes how to best represent some important features that are common to most long range planning models. (a) Planning horizon length. (b) Ending conditions. The final period of the planning model frequently needs special treatment. In some situations you may be able to actually use an infinite horizon plan. (c) Period length. (d) Uncertainty. What is the best way of representing it? Variance, downside risk, Value-at-Risk, a utility function of some sort? (e) "Nervousness" and "sliding scheduling". Most planning models are used in a "rolling or "sliding fashion, e.g., solve a 12 period model this month, implement the first period, and then next month slide things forward and repeat. When this is done, "nervousness may be a problem, i.e., the plan made in February for what to do in June may differ substantially from what the plan published in January suggested for June. (f) Changeover, startup and shutdown costs. (g) Precedence constraints. (h) Scarce resource constraints. (i) Taxes. These can be important in some planning models. How these are properly calculated, or at least approximated, in an optimization model can be a challenge in the presence of features such as depreciation and choice of FIFO vs. LIFO inventory valuation. (j) Nonlinearities.

## ■ MC48

North Bldg 229B

### Modeling Sustainability and Energy

Sponsored: Energy, Natural Res & the Environment Environment & Sustainability

Sponsored Session

Chair: Zana Cranmer, Bentley University, 175 Forest Street, Waltham, MA, 02452, United States

#### 1 - Effect of Nuclear Waste Management Costs on the Economic Viability of Nuclear Energy as a Low Carbon Energy Option

Robert Barron, Western New England University, Lawrence, KS, 66047, United States, Mary C. Hill

We consider how a more realistic treatment of the nuclear waste disposal than has been used in previous studies could affect the viability of nuclear power in the context of integrated assessments of climate change. Our results suggest that the optimism reflected in previous works is fragile: More realistic nuclear waste management cost models and uncertainty-appropriate inter-generational discount rates produce many more scenarios in which nuclear waste management costs are higher than previously assumed, and nuclear energy's economic attractiveness as a low carbon energy option is lower than earlier works suggested.

#### 2 - Competition Between Subsistence and Organized Retailers

Jiwen Ge, Postdoc, Tuck Business School, Woodbury 005, 100 Tuck Mall, Hanover, NH, 03755, United States, Brian Tomlin, Jan C. Fransoo

Subsistence retailers are independent small stores through which store owners provide for their family's subsistence needs. We study the competition between subsistence retailers and an organized retailer in an emerging market setting. For a model without consideration of the supplying manufacturer, we show the entry of the organized retailer could be detrimental to subsistence retailers. However, if we include the manufacturer in our analysis, we show that he is incentivized to set a favorable price so that subsistence retailers can survive sustainably.

#### 3 - Look-ahead Selection Strategy for Genomic Selection: Optimizing selection and Pairing Strategies with a Time-dependent Approach

Guiping Hu, Iowa State University, 3014 Black Engineering, Ames, IA, 50011, United States, Saba Moeiniazade, Lizhi Wang, Patrick Schnable

Genomic selection (GS) techniques allow breeders to make decisions with the genotypic data at an early stage. A major limitation of existing GS approaches is

the tradeoff between short-term genetic gains and long-term growth potential. Our contribution is to define a new look-ahead metric for assessing a selection decision, which evaluates the probability to achieve both genetic diversity and breeding deadline. Moreover, we propose a heuristic algorithm to find an optimal selection decision with respect to the new metric. Our new selection method is outperforming the other selection methods in the literature.

#### 4 - Spatially General Probabilistic Prediction Model for Wind Power Output

Kristen Schell, Postdoctoral Research Fellow, Polytechnique Montreal, 2900 Edouard Montpetit Blvd, Montreal, QC, H3T 1J4, Canada, Andrea Staid, Seth Guikema

Government incentives, such as production tax credits, have successfully spurred investment in wind power. Yet, this wind power is increasingly curtailed - deemed unusable by the power system - at astonishing rates. This reality highlights a knowledge gap in how to site wind farms that best contribute to power system resource adequacy. Using meteorological and historical wind power output data from several wind farms across different terrains, we develop a probabilistic prediction model for wind power output. This model gives the cumulative distribution function of predicted power output at any location, allowing system planners to prioritize wind farm development in high-producing locations.

#### 5 - The Drivers of Renewable Energy Innovation; An Empirical Analysis

Saeedeh Anvari, Postdoctoral Researcher, Darden School of Business, 136 University Gardens, Charlottesville, VA, 22903, United States, Michael J. Lenox

In this paper, we analyze the drivers of renewable energy innovation with the goal of discerning what drives both the rate and direction of innovative activity. We focus on public sector financing, private sector investments, and policy support for innovation as potential important drivers. Empirically, we measure innovation, using patents, across different economic regions in the US leveraging differences in regional ecosystems to tease out the impact of specific drivers.

## ■ MC49

North Bldg 230

### Big Data Analytics for Higher Education Industry

Contributed Session

Chair: Roger R. Gung, University of Phoenix, 3842 E. Windsong Dr., Phoenix, AZ, 85048, United States

#### 1 - Analytics Framework for Higher Education Industry

Roger R. Gung, Sr. Director, Business Analytics & Operations Rese, University of Phoenix, 4025 S. Riverpoint Parkway, Phoenix, AZ, 85048, United States

We present an end-to-end analytics framework for adult learning/higher education industry that covers solution methods with using big data analytics for the management of marketing, enrollment service, learning platform, academic performance and institutional finance.

#### 2 - Improve Academic Performance by Optimizing Faculty Assignment

Mei Duanmu, University of Phoenix, 4025 S. Riverpoint Parkway, Phoenix, AZ, United States, Jianhua Duanmu, Roger Gung

It is difficult to evaluate teachers' effectiveness in the educational industry, due to the non-random assignment of students to teachers. The performance for some teachers are overestimated/underestimated, because they teach the good/bad students. In order to filter out the impact of student quality difference, we developed the mixed effects model using student attributes as fixed effect and teacher impact as random effect. Separate models are developed for hundreds of courses in University of Phoenix. Based on the model outputs, teachers are then ranked by their effectiveness from top to down, which are used to guide the teacher assignment for future course sessions. Compared to random assignment, we see significant and consistent improvements in student performance by assigning teachers based on their rankings.

#### 3 - Hadoop Big Data System for eCampus and Educational Analytics

Jixiang Fang, University of Phoenix, Phoenix, AZ, United States, Jianhua Huang, Roger Gung

Big data is a technique to build a data platform for collecting and managing large volume or high dimensional data. Nowadays, many companies begin to increase their information technology investment in the big data field. A well-designed big data system is reliable for data mining and decision making. Hadoop system is a popular big data framework for storing data and running applications such as statistical programming software. This data system at the University of Phoenix (UOP) has been developed in the past 8 years by the data team and it is used to collect and synchronize the data of student learning activities and faculty teaching activities that were posted on the eCampus platform. In this presentation, the big data system at UOP will be an example to illustrate the procedure for using big data.



#### 4 - Big Data and Institutional Research with a Focus on Job Monitoring and Education Program Transformation

Grace Lin, Asia University and Chinese Medical University, Asia University, Taichung, 110, Taiwan, Weiting Chen, K. H. Chen, M.D. Chen, Y. J. Chung, C. T. Lee, Brick Tsai, Y. L. Tsai, Jeffrey Tsai, Tingying Young, YiJianian Zheng

The rapid changing business environment and technologies have led to a shortage of talents. Education Institutions often fail to adapt their education programs fast enough to meet the changing industry talent needs. The objective of this research is to develop a job monitoring and education model to understand up-to-date talent and skill needs and to identify gaps between talent needs and the education programs to facilitate the intuitions' course/program transformation and students' personal development plans. In this talk, we will report our system design and analysis based on data from our university's education system and Taiwan's job market. We will also discuss current gaps and our recommendations

#### 5 - A New Model for Supply Chain Finance

Grace Lin, Asia University and Chinese Medical University, Asia University, Taipei, 110, Taiwan, K. H. Chen, Brick Tsai

It's been extremely challenging for SMB to get financial support due to the lack of credit rating information and mechanism. In this research, we propose to leverage Supply Chain network information as well as advanced NLP, multi-source learning and stochastic network modeling, analysis and optimization to better assess SMB's crediting rating and risks and to provide financial services either through loan, P2P or crowd sourcing as needed. In this talk, we will present the analysis framework and discuss some preliminary analysis using realistic data.

### ■ MC50

North Bldg 231A

#### Behavioral Aspects Through the Lens of System Perspectives

Emerging Topic: Behavioral Aspects of OR

Emerging Topic Session

Chair: Martin Kunc, University of Warwick, Coventry, CV4 7AL, United Kingdom

##### 1 - How Big Data Can Contribute to System Dynamics Modeling

Hamed Kianmehr, State University of New York at Binghamton, Binghamton, NY, 13905, United States, Nasim S. Sabounchi, Lina Begdache

Our objective in this research is to use big data techniques to enhance system dynamics (SD) modeling regarding the relationship between diet and mood. We apply our approach to study the relationship between diet and mood. We estimate the parameters of the system dynamics model by applying some big data techniques on a large data set. Then, we feed the calibration parameters in SD models with the new estimations using big data analytics. Mixing these two different techniques based on longitudinal data provides more insights to develop more accuracy in SD models. Big data techniques and SD models can contribute to bringing more evidence to investigate the causal relationships between nutrition and mood.

##### 2 - Supply Management and Supply Risk

Burcu Tan, Assistant Professor, University of New Mexico, Albuquerque, NM, 87106, United States, Gokce Esenduran, John Gray

In this paper, we examine whether, when, and how common supply chain risk management practices relate to realized supply risk. We employ system dynamics modeling with realistic parameters to illustrate situations where certain practices can inadvertently increase supply risk.

##### 3 - Behaviour Based Pricing in Sharing Economy

Mojtaba Araghi, Lazaridis School of Business and Economics, Wilfrid Laurier University, 75 University Ave W, Waterloo, ON, N2L 3C5, Canada, Tina Arabian, Hamid Noori

In sharing economy and servicizing business models, where firms sell the functionality of a product rather than the product itself, customers have less incentives to consider the long term economical and environmental impacts of their usage behaviours. Implementing new technologies, such as Internet of Things (IOT), firms now can track how well customers are using the shared product. This study introduces a behavior-based pricing that consider the behaviour of customers in addition to their amount of usage. We determine conditions under which adopting behaviour based pricing is more profitable and environmentally superior to the traditional pricing models.

### ■ MC51

North Bldg 231B

#### Production Planning and Scheduling in Operations

Emerging Topic: Project Management and Scheduling, in Memory of Joe Leung,

Emerging Topic Session

Chair: Chelliah Sriskandarajah, Texas A&M University, College Station, TX, 77843-4217, United States

Co-Chair: Yunxia Zhu, University of Nebraska-Lincoln, Lincoln, NE, United States

##### 1 - Optimal Stocking for Substitutable Products

Vashkar Ghosh, University of Florida, P.O. Box 117169 356 Stuzin, Dis Dept Warrington College of Bus, Gainesville, FL, 32611-7169, United States, Anand Paul

We study the optimal stocking of product variants of a retailer facing random product demand. Each customer who arrives has a preferred first-choice product variant, but will exercise a second-choice in the event that the first-choice variant is not available. We find the structural form of the optimal stocking quantities in a single period as well as over an infinite horizon, and show that it differs systematically from the 'naive' news-vendor solution.

##### 2 - Optimal Structure of Joint Inventory-Pricing Management with Dual Suppliers

Houmin Yan, City University of Hong Kong, Dept of Management Sciences, Kowloon Tang, Hong Kong

Abstract not available.

##### 3 - Three-machine Open Shop with a Bottleneck Machine Revisited

Inna Drobouchevitch, Korea University Business School, Seoul, Korea, Republic of

We consider the three-machine open shop scheduling problem to minimize the makespan. In the model, each job consists of two operations, one of which is to be processed on the bottleneck machine, the same for all jobs. A new linear-time algorithm to find an optimal non-preemptive schedule is developed. The suggested algorithm considerably simplifies the only previously known method as it straightforwardly exploits the structure of the problem and its key components to yield an optimal solution.

##### 4 - Cross-dock Terminal Scheduling

Yunxia Zhu, University of Nebraska-Lincoln, Lincoln, NE, United States, Harry Neil Geismar, Chelliah Sriskandarajah, Inna Drobouchevitch

We study various scheduling problems encountered in cross-dock terminals. The typical objective is to minimize the total time spent to perform unloading and loading for a planning horizon. We also study other objective functions under various cross-dock terminal environments (e.g., with no-wait processing and with the presence of temporary storage).

##### 5 - An Optimization Framework for Influencers in Social Media

Rakesh Reddy Mallipeddi, Texas A&M University, 320 Wehner - 4217, Mays Business School, Dept of Info&Operations, College Station, TX, 77843-4217, United States, Subodha Kumar, Chelliah Sriskandarajah, Yunxia Zhu

Influencer marketing, which involves hiring influential users of social media, is being increasingly employed by firms to market their products. In this study, we propose a data-driven analytical framework to answer the following questions from the perspective of a firm: (i) how many influencers to hire, (ii) whom to hire, (iii) how to schedule and sequence the content by multiple influencers. A pilot study conducted using data collected from Twitter demonstrates that our framework consistently outperforms the current industry practice of selecting influencers based on the reach of influencers by 10%-90%.

## ■ MC52

North Bldg 231C

### Social Influence in Shared Mobility

Emerging Topic: Social Media Analytics

Emerging Topic Session

Chair: Arif Mohaimin Sadri, Florida International University, Miami, FL, 33174, United States

#### 1 - Exploring the Effects of Social Resources on Leisure Activity and Autonomous Vehicle Intention

Michael Maness, University of South Florida

This presentation showcases results from a survey exploring the relationships between leisure activity variety and frequency and individuals' access to social resources. This includes general measures of social resource access, the position generator, and specific measures of social resource access, the resource generator. Additionally, the survey explores autonomous vehicle usage intention and its relation with access to information through interpersonal networks.

#### 2 - Social Influence during Emergency Evacuations: Evidence from On-line and Off-line Social Networks

Arif Mohaimin Sadri, Florida International University, Miami, FL, United States

Social networks serve the purpose of transmitting warning messages by disseminating information about an impending threat. Individuals having more social connections can be expected to receive more warning information. This study uses both ego-centric personal networks (off-line) and Twitter (on-line) data to understand social influence on evacuation responses during Hurricane Sandy.

## ■ MC53

North Bldg 232A

### Matching Theory II

Sponsored: Auction and Marketing Design

Sponsored Session

Chair: Umut Dur, NCSU, Raleigh, NC, 27695, United States

#### 1 - School Assignment with Siblings

William Phan, North Carolina State University, Raleigh, NC, United States, Thayer Morrill, Umut Dur

We study the problem of school assignment with siblings. Existing mechanisms used in centralized assignment do not formally account for such issues. As such, school districts implement ad hoc protocols that may result in instability and mismatched siblings. First, we propose a new notion of stability that takes into consideration the existence of siblings. Second, using the many-to-many matching with contracts framework, we propose a new mechanism that satisfies our proposed stability property and is strategy-proof. Using data from Wake County School District, we run a counterfactual analysis and show how our mechanism improves upon previous years' assignments.

#### 2 - Efficient and Incentive Compatible Liver Exchange

M. Utku Unver, Boston College, 140 Commonwealth Avenue, Chestnut Hill, MA, 02467, United States, Haluk Ergin, Tayfun Sonmez

Living-donor liver transplantation is widespread in parts of the world and living-donor liver exchange has already been practiced in several countries to overcome blood-type incompatibilities. A living donor can donate either his smaller left lobe or larger right lobe, although the latter is substantially riskier. Despite the elevated risk, right-lobe donation is often utilized due to size compatibility requirements. We model liver exchange as a market design problem, focusing on the logistically simpler two-way exchanges. We introduce an individually rational, Pareto-efficient, and incentive-compatible mechanism that truthfully elicits the right-lobe donation willingness of donors.

#### 3 - Strategy-proof Size Improvement: Is It Possible?

Umut Dur, NCSU, 2801 Founders Drive, 4102 Nelson Hall, Raleigh, NC, 27695, United States, Oguz Afacan

In object allocation problems, we say that a mechanism size-wise dominates another mechanism if the latter never allocates more objects than the former does, while the converse is true for some problem. Our main result shows that no individually rational and strategy-proof mechanism size-wise dominates a non-wasteful, truncation-invariant, and extension-responding mechanism. We also show that whenever the number of agents does not exceed the total number of object copies, no group strategy-proof and efficient mechanism, such as top trading cycles mechanism, is size-wise dominated by an individually rational, weakly population-monotonic, and strategy-proof mechanism.

#### 4 - Assigning Course Schedules: About Preference Elicitation, Fairness, and Truthfulness

Martin Bichler, Technische Universität München, Department of Informatics, Boltzmannstr. 3, Munich, 85748, Germany, Soeren Merting

Course assignment is a wide-spread problem in education. Often students have preferences for bundles of course seats or course schedules over the week, which need to be considered. Bundled Probabilistic Serial (BPS) is a randomized mechanism satisfying ordinal efficiency, envy-freeness, and weak strategy-proofness. We report a first application of BPS in a large-scale course assignment application at the Technical University of Munich. In particular we focus on preference elicitation, which is challenging due to the combinatorial explosion of packages.

## ■ MC54

North Bldg 232B

### Joint Session BOM/Practice Curated: Experimental Supply Chain Management

Sponsored: Behavioral Operations Management

Sponsored Session

Chair: Andrew M. Davis, Cornell University, Cornell University, Ithaca, NY, 14853, United States

#### 1 - Private Information and Endogenous Matching in Supply Chains: Theory and Experiments

Kyle Hyndman, University of Texas at Dallas, 800 W. Campbell Rd, SM31, Richardson, TX, 75080, United States, Andrew M. Davis

We investigate a supply chain setting where a supplier's cost may be private information (but they may disclose it) and buyers and suppliers may endogenously match into pairs. After forming pairs, the two parties engage in a dynamic bargaining setting. Suppliers always make less than theory predicts, whether their cost is known or private information. This effect is especially pronounced under private information for high cost suppliers, because buyers make more aggressive bargaining offers in such a setting. Thus, contrary to theory, a second result is that higher cost suppliers actually benefit from disclosing their private costs, in an effort to achieve a more favorable outcome while bargaining.

#### 2 - The Commitment Conundrum of Inventory Sharing

Shan Li, City University of New York, Baruch College, 55 Lexington Avenue, New York, NY, 10010, United States, Kay-Yut Chen

In this paper, we take a behavioral lens to study the impact of different transfer price contracting schemes and inventory sharing schemes on local decision making of decentralized retailers, constructing a behavioral model, incorporating bounded rationality, fairness, and psychological pain of excess supply to explain the findings.

#### 3 - Is Simplicity the Ultimate Sophistication? Wholesale Pricing vs. Non-linear Pricing

Behrooz Pourghannad, University of Minnesota, Minneapolis, MN, United States, Guangwen Kong, Tony H. Cui

This paper studies a manufacturer's choice of contract when facing a boundedly rational retailer. In a supply chain with a fully rational retailer a wholesale price contract cannot perform better than buy-back and revenue sharing contracts. When the retailer is boundedly rational, we find that a wholesale price contract can dominate both buy-back and revenue sharing contracts. We characterize the condition under which a wholesale price contract is the optimal choice of the manufacturer. Our findings are supported by laboratory experiments in which human suppliers choose a contract to offer to computerized boundedly rational retailers.

#### 4 - Auctions, Efficient Coordination, and Strategic Complementarities

James Fan, Naval Postgraduate School, Monterey, CA, United States, Anthony Kwasnica

Do auctions always lead to efficient production outcomes? We examine this question in a team coordination game, and we find that the degree of coordination as a result of an auction is sensitive to the degree of strategic complementarity. Our results are examined in relationship to the behavioral learning model proposed by Crawford and Broseta (1998).

## ■ MC55

North Bldg 232C

### Navigating NSF: Funding Opportunities at NSF

Emerging Topic: NSF

Emerging Topic Session

Chair: Georgia-Ann Klutke, National Science Foundation, Arlington, VA, 22230, United States

#### 1 - Navigating NSF: Funding Opportunities at NSF

Georgia-Ann Klutke, National Science Foundation, National Science Foundation, Arlington, VA, 22230, United States

The National Science Foundation (NSF) offers a number of funding opportunities for investigators working in the fields of industrial engineering and operation research, both within the disciplinary programs in Engineering and other directorates, and through cross-cutting initiatives that are foundation-wide. This presentation will describe opportunities that are relevant to the Industrial and Operations Engineering communities, with particular emphasis on the Operations Engineering program in the Division of Civil, Mechanical & Manufacturing Innovation. The talk will also briefly describe guidelines for proposal preparation and NSF's Intellectual Merit and Broader Impacts criteria. Question-and-answer session will follow the presentation.

## ■ MC56

West Bldg 101A

### HAS Distinguished Scholar Lecture

Margaret L. Brandeau

Sponsored: Health Applications

Sponsored Session

Chair: Ebru Korular Bish, Virginia Tech, Blacksburg, VA, 24060, United States

Co-Chair: Tinglong Dai, Johns Hopkins University, Baltimore, MD, 21202, United States

#### 1 - What Should We do About the Opioid Epidemic? Models to Support Good Decisions

Margaret L. Brandeau, Stanford University, Management Science and Engineering, 475 Via Ortega, Stanford, CA, 94305-4026, United States

The US is currently experiencing an epidemic of drug abuse caused by prescription opioids and illegal opioid use, including heroin. In addition to crime and social problems, rising levels of drug abuse have led to a sharp increase in overdose deaths as well as significant outbreaks of infectious diseases such as HIV and hepatitis C. How should we deploy limited public health resources to help solve this complex public health problem? This talk describes models used to support decision making regarding the control of drug abuse — and associated diseases such as HIV and hepatitis C — in the US. We conclude with discussion of key areas for further research.

## ■ MC57

West Bldg 101B

### Joint Session HAS/AI: Deep Learning in Healthcare

Sponsored: Health Applications

Sponsored Session

Chair: Gordon Gao, MD, United States

#### 1 - A Deep Learning Architecture for Psychometric Natural Language Processing

Jingjing Li, PhD, University of Virginia, Charlottesville, VA, United States, Ahmed Abbasi, Faizan Ahmad, Hsinchun Chen

We propose a novel deep learning architecture -PyNDA- to extract psychometric dimensions from user-generated texts in a timely and unobtrusive manner. PyNDA contains a representation embedding, a demographic embedding, a structural equation model encoder, and a multitask learning mechanism designed to address the unique challenges associated with extracting sophisticated and user-centric psychometric dimensions. Our experiments on three real-world datasets encompassing eleven psychometric dimensions, including trust, anxiety, and literacy, show that PyNDA markedly outperforms traditional feature-based classifiers as well as the state-of-the-art deep learning architectures.

#### 2 - Deep-learning-based Approach for Precise Health Cost Prediction

Weiguang Wang, University of Maryland, 3330 B. Van Munching Hall, College Park, MD, 20742, United States, Margret V. Bjarnadóttir, Guodong (Gordon) Gao

Healthcare cost predictions have multiple applications, however precisely predicting healthcare costs at the individual patient level remains a challenge in the machine learning domain. In this study, long short-term memory based recurrent neural network is proposed to incorporate the sequential healthcare cost information for more accurate healthcare cost predictions. We compare the performance of our deep learning approach with multiple traditional machine learning methods. Among all the methods, deep learning shows the best performance. Finally, the performance of deep learning is explained using subgroup analyses and pattern extraction.

#### 3 - Automated Depression Detection Using Multimedia Data

Guohou Shan, University of Maryland-Baltimore County, Baltimore, MD, 21250, United States, Lina Zhou, Dongsong Zhang

Depression is a major mental health problem. Automated depression detection has been explored with social media content; however, it has been rarely studied using multimedia data such as audio and video. This research aims to improve automatic depression detection by incorporating new predictive features and by identifying fine-grained indicative content.

## ■ MC58

West Bldg 101C

### Incentives in Healthcare

Sponsored: Health Applications

Sponsored Session

Chair: Burhaneddin Sandikci, University of Chicago, Chicago, IL, 60637, United States

#### 1 - Expanding the Donor Pool: The Use of Marginal Organs for Transplantation

Sait Tunc, University of Chicago, McGiffert House 4th Floor, 5751 S. Woodlawn Avenue, Chicago, IL, 60637, United States, Burhaneddin Sandikci, Bekir Tanriover

Transplantation emerged as the standard treatment for organ failure. Despite the growing shortage for donor organs as demand outpaces supply, a significant fraction of organs harvested for transplantation are rejected and discarded. As a viable option to alleviate the burden of shortages, we study the use of marginal organs for transplantation through a queueing-theoretic framework. We investigate socially efficient and equilibrium utilizations of donor organs, and discuss incentive mechanisms that help increase the utilization of marginal organs while also improving overall social welfare.

#### 2 - Contracts to Improve Vaccine Effectiveness and Availability

Taylor Corcoran, UCLA Anderson School of Management, 110 Westwood Plaza, Los Angeles, CA, 90024, United States, Fernanda Bravo, Elisa Long

Two key players in vaccine markets are pharmaceutical companies, who develop and manufacture vaccines, and global health organizations (GHOs), who procure vaccines for low- and middle-income countries. The payment that pharmaceutical companies receive from GHOs depends on the quantity of vaccines produced, but is independent of their effectiveness, which may lead to the development of low quality vaccines that make it more difficult for GHOs to achieve their public health targets. To address this inefficiency, we use a game-theoretic model that incorporates disease dynamics to analyze performance-based contracts which link vaccine price and effectiveness.

#### 3 - Data Driven Incentive Design in the Medicare Shared Savings Program

Auyon Siddiq, UCLA Anderson School of Management, Los Angeles, CA, United States, Anil Aswani, Max Shen

The Medicare Shared Savings Program (MSSP) was created to control escalating Medicare spending by incentivizing providers to deliver healthcare more efficiently. We formulate the MSSP as a principal-agent model and propose a new type of contract that includes a performance-based subsidy for the provider's investment. We show that the proposed contract dominates the existing MSSP contract by producing a strictly higher expected payoff for both Medicare and the provider. We then present an estimator based on inverse optimization for estimating the parameters of the principal-agent model and the potential increase in savings under the proposed contract.



## ■ MC59

West Bldg 102A

**Healthcare Operations**

Sponsored: Health Applications

Sponsored Session

Chair: Hessam Bavafa, The Wisconsin School of Business

**1 - Who Is an Efficient and Effective Physician? Evidence from Emergency Medicine**

Raha Imanirad, Harvard Business School, Boston, MA, 02472, United States, Soroush Saghaian, Stephen J. Traub

Improving the performance of the healthcare sector requires a deep understanding of the efficiency and effectiveness of care delivered by providers. Despite recent advances, fair and scientific methods of measuring efficiency and effectiveness of care delivery have proven elusive. In this study, we use evidence from care delivered by emergency physicians in conjunction with Data Envelopment Analysis (DEA), and shed light on scientific metrics that can gauge performance in terms of efficiency and effectiveness. We then carry out a Tobit analysis to identify factors related to patient, physician and peer physician characteristics that are associated with higher levels of physician performance.

**2 - Process Innovation in the Pharmaceutical Industry: Evidence from the Manufacturing of Generics**

Dimitrios Andritsos, HEC Paris, Departement MOSI, 1 Rue De La Liberation, Jouy-en-Josas, 78351, France, Ivan Lugovoi, Claire Senot

We explore the economic effects of process innovation on pharmaceutical manufacturing. Through a collaboration with expert patent attorneys we construct a unique dataset that: i) evaluates process innovation through a detailed observation of pharmaceutical manufacturers' portfolios of process patents and ii) measures key qualitative dimensions of process innovation, such as novelty, strength of protection and locus of application.

**3 - Elective Admission and Patient Discharge Policies in Hospital Environments**

Vaniitha Virudachalam, The Wharton School, 3730 Walnut Street, 500 Jon M. Huntsman Hall, Philadelphia, PA, 19104, United States, Sergei Savin, Hessam Bavafa, Lerzan E. Ormeci

We consider the problem of managing the profitability for a hospital faced with a particular reimbursement structure. We assume that the hospital can utilize two main levers: patient admissions, through the size and composition of its portfolio of elective procedures, and early discharges, which modify the patient length-of-stay distribution and relieve pressure on hospital resources. For each type of procedure, we find the optimal admission rate and discharge threshold. We characterize these values under different reimbursement structures and cost structures.

**4 - Customized Optimal Diabetes Screening Policies in Resource-restricted Settings**

Michael Hahsler, Southern Methodist University, Bobby B. Lyle School of Engineering, P.O. Box 750123, Dallas, TX, 75275, United States, Hossein Kamalzadeh, Vishal Ahuja, Michael Bowen

About 10% of the US adult population has diabetes, and almost 40% are at risk of developing diabetes. Guidelines suggest population-based screening, however, in resource-restricted settings (e.g., for safety-net providers), prioritizing whom to screen and when is essential. We combine analytics methods (hidden Markov models and predictive analytics) with partially observable Markov decision process models to derive the optimal screening policy customized to the characteristics of the provider's subpopulation. We will present results for electronic health record data from the Parkland Health & Hospital System.

## ■ MC60

West Bldg 102B

**Modeling and Optimization in Organ Transplantation**

Sponsored: Health Applications

Sponsored Session

Chair: Murat Kurt, Bristol-Myers Squibb, 3401 Princeton Pike, Lawrence Township, NJ, 08648, United States

Co-Chair: David L. Kaufman, University of Michigan-Dearborn, Dearborn, MI, 48126, United States

**1 - Investigating Steroid Withdrawal Strategies for Kidney Transplant Recipients**

Yann Ferrand, Clemson University, Clemson, SC, United States, Christina M. Kelton, Vibha Desai, Teresa M. Cavanaugh, Jaime Caro, Jens W. Goebel, Pamela C. Heaton

We study long-term complications associated with various steroid withdrawal

strategies for kidney transplant recipients. We develop a model calibrated with an econometric study of patient data from a national registry to simulate the long-term course of these patients, and derive patient outcomes based on the characteristics of patient population. We study the role of patient heterogeneity on health outcomes, and the relative risk of steroid withdrawal versus steroid maintenance.

**2 - Comparison of Post-transplantation Diabetes Mellitus Features and Outcomes in Kidney, Liver, and Heart Transplantation Patients**

Vidit Munshi, Harvard University, Cambridge, MA, United States, Soroush Saghaian, Curtiss Cook, Harini Chakkera

Corticosteroids and immunosuppressive agents prevent graft rejection in transplantation patients, but also bring significantly increased risk for development of impaired glucose tolerance and post-transplantation diabetes mellitus. While this tradeoff is well-known, little work exists characterizing similarities and differences in these tradeoffs across different organ transplantations, particularly from the same hospital system. We present empirical work comparing characteristics and outcomes across kidney, liver and heart transplantation patients and propose a method for modeling these patients to assess interventions and determine optimal management strategies.

**3 - Strategic Decisions of Transplant Centers under Competition**

Sait Tunc, University of Chicago, IL, United States, Burhaneddin Sandikci, Bekir Tanriover

Transplant centers in the United States are regularly evaluated for their transplant-related performance. Considering the consequences of their performance outcomes, centers strategically accept/reject offered organs. We study the equilibrium behavior of a heterogeneous set of centers in a competitive market and investigate the effect of their decisions on social welfare.

## ■ MC61

West Bldg 102C

**Telecommunication Networks Optimization**

Sponsored: Telecommunications and Network Analytics

Sponsored Session

Chair: Eric Gourdin, France Telecom, Orange Labs, CORE/TPN, France Telecom, Orange Labs, CORE/TPN, Issy les Moulineaux Cedex 9, 92794, France

Co-Chair: Ivana Ljubic, ESSEC, France

**1 - Implications of Zero Rating Programs on Consumer Welfare: A Model Based Study**

Jialin Song, University of Illinois at Urbana Champaign, 104 S. Mathews Avenue, Urbana, IL, 61801, United States, Qiong Wang

Mobile Service Providers (MSPs), such as AT&T, have introduced several zero-rating programs, allowing Content Providers (CPs) to pay for data usage on behalf of customers. However, some worry that zero-rating behavior may hurt the welfare of customers of a MSP's existing data plans. We develop a linear integer programming model and a dynamic programming solution procedure to analyze MSP's optimal offering of data plans and the impact of zero rating. We carry out numerical experiments to examine the implications of zero-rating programs with respect to the clustering algorithms to aggregate subscribers into groups, data demand and willingness to pay associated with each group and their correlation.

**2 - Clique Interdiction Attacks in Networks**

Ivana Ljubic, ESSEC Business School of Paris, 3 Av. Bernard Hirsch B.P. 50105, 3rd floor, office 315, Cergy, 95021, France

We consider a leader-follower game where the leader removes a fixed number of vertices, and the follower finds the maximum clique over the remaining network. The leader searches for the vertex removal policy that minimizes the largest remaining clique. The problem has applications in the surveillance of communication networks. We provide results concerning the problem complexity and polyhedra, combinatorial lower bounds and safe reduction techniques. We implement a useful tool for analyzing the resilience of (social) networks with respect to vertex-interdiction attacks. Networks with up to 3M edges can be analyzed and solved to optimality within short computing times.

**3 - A Flexible Natural Formulation for the Network Design Problem with Vulnerability Constraints**

Okan Arslan, HEC Montreal, Montreal, QC, Canada, Ola Jabali, Gilbert Laporte

Given a graph, a set of origin-destination (OD) pairs with communication requirements and an integer  $k$ , the network design problem with vulnerability constraints (NDPVC) is to identify a subgraph with the minimum total edge costs such that between each OD pair, there exist a hop-constrained primary path, and a hop-constrained backup path after any  $k-1$  edges of the graph fail. We develop a natural formulation based on the notion of length-bounded cuts. Experimental results show that for single edge failures, our formulation increases the number of solved benchmark instances from 61% to over 95%. Our formulation also efficiently solves the NDPVC for multi-edge failures ( $k=3$ ).

## ■ MC62

West Bldg 103A

### Deep Learning Methods for Manufacturing Processes

Sponsored: Data Mining

Sponsored Session

Chair: Chitta Ranjan

Co-Chair: Kamran Paynabar, ISyE, Georgia Institute of Technology

#### 1 - Apply Deep Learning to Powder Bed Fusion Process Physics in 3D Printing

He Luan, HP Labs, HP Inc., Palo Alto, CA, United States, Sam Stodder, Jordi Roca, Jun Zeng, Qiang Huang, David Murphy, Thomas Paula

Informed by physical knowledge, the powerful learning ability of deep learning has huge potential to model and understand the complicated physical behaviors, such as fusing principles involved in powder bed fusion based 3D printing. Using HP's Multi Jet Fusion (MJF) as an example, this research demonstrates how deep learning can be applied to model and explore process physics. In first application, deep neural network models were built to predict the voxel level fusing layer thermal behavior from multiple thermal influencers. The second application models the heterogeneous material thermal diffusivity as a deep neural network, to enable both in-situ thermal prediction and better understanding.

#### 2 - Online and Active Learning-based Classifier for Non-scalable Media Data

Geet Lahoti, ISyE, Georgia Institute of Technology, 1038 Mcmillan St. NW, Atlanta, GA, 30318, United States, Chitta Ranjan, Chuck Zhang

Typically dimension reduction is performed prior to building a classification model for high-dimensional data. However, how to build a classifier for high-dimensional data when dimension reduction is not possible? Consider a problem where sheet metals are to be classified as defective or non-defective using their large images. In this situation, when the defect size is extremely small in comparison to the image, rescaling of the image often loses the defect signal. Such a problem is more pronounced in various video datasets. To address this, we develop a new approach using Active and Online Learning that uses a combination of strongly and weakly labeled data to build a defect classifier.

#### 3 - Nonlinear Profile Monitoring via Variational Autoencoder

Hao Yan, 699 S. Mill Ave, Tempe, AZ, 85281, United States

Unsupervised learning of nonlinear profiles has attracted increasing attention among researchers as well as practitioners because of its applications in process monitoring and diagnostics. However, existing unsupervised learning techniques for profile monitoring are typically based on linear models such as Principal Component Analysis, which fails to model the distribution of nonlinear profiles. We present a unified framework for nonlinear profile monitoring based on variational autoencoder, which a testing statistics can be naturally derived. We then demonstrate how this framework can be used for denoising and profile monitoring with various simulations and case studies.

#### 4 - A Novel Classification Deep Boltzmann Machine (C-DBM) for Supervised Learning

Samaneh Ebrahimi, Georgia Institute of Technology, Atlanta, GA, 30318, United States, Kamran Paynabar

The Restricted Boltzmann Machine (RBM) is a probabilistic model to model the distribution of a visible layer of features using one hidden layer. Deep Boltzmann Machines were developed as an extension of RBM with multiple hidden layers. These methods have been successfully applied for unsupervised learning. In 2009, Larochelle and Bengio proposed a new discriminative RBM for supervised learning known as Classification RBM (CRBM). Due to estimation intractability, an effective deep extension of CRBM has not been used in the literature. In this paper, we propose a new estimation approach for deep CRBM (C-DBM). Moreover, we implement this approach on a manufacturing process for validation.

## ■ MC64

West Bldg 104A

### Joint Session DM/Practice Curated: Data Science and Analytics to Manage Power and Water

Sponsored: Data Mining

Sponsored Session

Chair: Durai Sundaramoorthi, Saint Louis, MO, 63130, United States

#### 1 - Time Varying Optimization and Learning in Power Systems

Jiafan Yu, Stanford University, Stanford, CA, United States, Siobhan Powell, Ram Rajagopal

Traditional approaches to reactive power management in distribution networks have focused on designing stable and near-optimal centralized or distributed

control schemes under the assumption that network physics constraints are completely known. In this talk, we explore an alternative approach that learns a control procedure by observing streams of measurements from the system. We show that a simple batch learning and optimal control procedure attains comparable performance to existing approaches without requiring any prior knowledge of the network and give some analytical guarantees. We then show how the procedure can be utilized to construct an online learning process for the problem.

#### 2 - Exploration of Machine Learning Techniques in Time Series pH Prediction in Water Distribution System

Xiushuang Li, Arizona State University, Tempe, AZ, 85281, United States, Daniella Sietta, Pitu B. Mirchandani, Treavor Boyer

Accurate prediction of the system state is extremely important in controlling water distribution system. Machine learning appears to be a great way to estimate and predict the state of the dynamic system. We explored the application of Symbolic Regression (SR), Lasso Regression (LR) and Neural Network models (NN) to predict time series pH in a small water distribution system. All three methods can achieve comparable accuracy ( $R^2 > 0.93$ ), but LR and NN models take much less time to train than SR model. LR can also filter insignificant input variables in pH prediction by forcing their coefficients to be zero. Both LR and NN can be a useful tool to build the predictive model in water distribution system control.

#### 3 - A Bayesian Forecasting Model of Electric Outages

Luis J. Novoa, James Madison University, Harrisonburg, VA, United States, Babak Zafari, Goran Vojvodic, Refik Soyer

As an aid for planning and preparation against severe weather events we propose a forecasting model for electric outages under a bayesian framework. We applied the model using real data.

## ■ MC65

West Bldg 104B

### Data Science and Artificial Intelligence I

Sponsored: Data Mining

Sponsored Session

Chair: Evan Barlow, Weber State University, Goddard School of Business & Economics, 1337 Edvalson St, Ogden, UT, 84408, United States

#### 1 - Thermodynamics of Markov Decision Processes

Peeyush Kumar, University of Washington-Seattle, Seattle, WA, United States

This research introduces information theoretic methods inspired by stochastic thermodynamics for MDPs with model uncertainty. Specifically, this research models the physical aspects of information into system dynamics. I will show an explicit link between the information entropy and the stochastic dynamics of a system coupled to an environment. We analyze various sources of entropy production: due to the decision maker's uncertainty about the system-environment interaction characteristics, and the stochastic nature of system dynamics. This analysis provide a formulation that enables us to define the optimality criterion for MDPs with model uncertainty.

#### 2 - If You Can't Beat Them, Join Them: Collective Intelligence Outperforms Artificial Intelligence at Diagnosing Skin Cancer

Erik P. Duhaime, Massachusetts Institute of Technology, 100 Main Street, e62-390, Cambridge, MA, 02142, United States

A growing chorus of academics, thought leaders, and politicians warn that artificial intelligence will cause unprecedented job loss, even among highly trained knowledge workers such as doctors. At the same time, advances in information technology have enabled entirely new ways of organizing work, and research has shown that crowds of people oftentimes outperform even their most highly skilled individual members. Here, I leverage a dataset of the diagnoses of 1 state-of-the-art artificial intelligence system and 21 board-certified dermatologists in order to examine what happens when artificial intelligence is combined with - rather than compared to - human intelligence.

#### 3 - Learning Hidden Markov Models with Regulated Initialization using Multinomial Regression

Akash Gupta, Oklahoma State University, 40 South University Place, Stillwater, OK, 747075, United States, Tieming Liu, Christopher Crick, Dursun Delen

Hidden Markov Models (HMMs) are widely used for developing disease progression models. Learning parameters of HMMs using Baum-Welch (BW) algorithm with random initialization is a computationally expensive task. In this work, we propose a regulated initialization framework for BW algorithm using multinomial logistic regression that allows early convergence. The preliminary results showed improvement of 68 - 90% compared with random initializations. The proposed method facilitates the development of disease progression model with high granularity in disease states.

#### 4 - A Novel, Scalable Machine Learning Task Capable of Superhuman Artificial Intelligence

Evan Barlow, Weber State University, Goddard School of Business & Economics, 1337 Edvalson St, Ogden, UT, 84408, United States

Machines often outperform humans in executing repetitive physical tasks. Leveraging machine learning, computers can now: (i) mimic human performance in repetitive mental tasks, or (ii) exceed human performance in complicated predictive tasks. Prediction is most fitting, however, when inputs and outputs are out of decision makers' control. Large-scale prescriptive analytics using optimization is very difficult (if possible at all) for most current machine learning tasks. The machine learning task presented here promises a scalable approach to superhuman decision making. The approach has successfully been applied to prescribe optimal decisions with several large-scale sandbox datasets.

#### ■ MC66

West Bldg 105A

#### Joint Session AI/Practice Curated: Healthcare Analytics: Machine Learning Approaches for Health Data

Sponsored: Artificial Intelligence

Sponsored Session

Chair: Hongyi Zhu

##### 1 - Automatic Diagnosis of Alzheimer's Disease Using Deep Neural Networks

Maryam Zokaeinikoo, Graduate Research Assistant, Pennsylvania State University, University Park, State College, PA, 16802, United States, Prasenjit Mitra

We propose different neural network models based on Long Short-Term Memory (LSTM) to detect the onset of Alzheimer's early in the course of the disease using textual data from both healthy subjects and patients. These models include LSTM networks, bidirectional LSTM (BLSTM), bidirectional LSTM with attention layer (Attention-BLSTM), and bidirectional LSTM with conditional random fields layer (CRF-BLSTM). Although the LSTM often requires large training datasets, our CRF-BLSTM algorithm demonstrates that even with limited training data it performs well in detecting the Alzheimer's disease. The results are validated using two methods of cross validation.

##### 2 - Computational Algorithms for Tracking Near Falls with Multiple Wearable Sensors

Alla Kammerdiner, New Mexico State University, Las Cruces, NM, United States, Razan Ayasra

A loss of balance that constitute near falls can be tracked with multiple body-worn accelerometers. We consider some new formulations for estimation and optimization problems related to tracking of near falls. We also present and analyze computational algorithms, which are used for space partitioning in statistical estimation and for solving the combinatorial optimization problems.

##### 3 - Seizure Detection Using a Hidden Markov Model Framework

Mahboubah Madadi, Louisiana Tech University, College of Engineering and Science, P.O. Box 10348, Ruston, LA, 71272, United States, Giovanni Petris, Leonidas Iasemidis

In this study, a hidden Markov models (HMM) is developed to automatically detect different brain states in epilepsy patients. The proposed HMM aims at characterizing the dynamics of intracranial electroencephalographic (iEEG) signals using important features such as generalized partial directed coherence (GPD). The iEEG signals from epilepsy patients, who underwent long-term monitoring of the brain electrical activity for subsequent surgical removal of their epileptogenic focus, were analyzed to classify a patient's state at a given point in time into one of four states: interictal (seizure-free / between seizures), pre-ictal (pre-seizure), ictal (seizure), postictal (post-seizure).

##### 4 - A Deep Learning Approach of Microarray Data Analysis in Cancer Prognosis

Sharmin Nahar Mithy, Doctoral Candidate, University of South Florida, Tampa, FL, 33612, United States, Grisselle Centeno

Research has shown that a major portion of cancers and related deaths could be prevented by applying existing knowledge about cancer treatment. In this research we present a deep learning approach for cancer gene identification. SDAE based clustering approach is applied here for feature extraction from Gene Expression Profiling and will be compared with some other methods. The performance of the extracted information will be evaluated to verify the usefulness of the new features. The extracted feature will further be utilized to predict the radio sensitivity for 48 cell line used as input in cancer treatment and patient prognosis. We expect to validate the data from 20 patients with rectal cancer.

#### ■ MC67

West Bldg 105B

#### Platforms and Peer-to-Peer Markets

Sponsored: Information Systems

Sponsored Session

Chair: Zaiyan Wei, Purdue University, Purdue University, West Lafayette, IN, 47907, United States

##### 1 - Is Home Sharing Making Housing Less Affordable? Evidence from a Natural Experiment on Airbnb

Wei Chen, Assistant Professor, University of Arizona, 1130 East Helen Street, Tucson, AZ, 85721, United States, Zaiyan Wei, Karen Xie

We study the impact of online home sharing on affordable housing. We leverage a "natural experiment" of a platform regulation that caps the number of properties a host can manage in some markets to estimate the impact. We find that the restriction was associated with a 3.5% decrease in local rental prices and a 1.9% decrease in housing value. The decrease can be attributed to the removal of absentee landlords' properties from Airbnb back to local markets. The price-to-rent ratio, however, increased by about 1.6%, which suggests that online home sharing is mainly a substitute for local rental markets. These findings speak to the question whether home sharing makes housing less affordable.

##### 2 - Does Political Polarization Decrease Market Efficiency: An Investigation in the Context of Online Lending

Hongchang Wang, Georgia Institute of Technology, 800 West Peachtree NW, Atlanta, GA, 30308, United States, Eric Overby

We study whether political polarization inhibits market efficiency by examining whether investors in online lending markets are less likely to lend to borrowers whose political ideology (i.e., liberal or conservative) is likely to be different from their own. We apply both a gravity model and a difference-in-differences model to find that borrowers in liberal states are more preferred than borrowers in conservative states (on average 5% more bids). In addition, borrowers are more likely to attract investors from politically similar states than investors from politically dissimilar states. We find that political distance deters online lending, with an impact of 1.8% for one standard deviation.

##### 3 - The Roles of Informed and Uninformed Backers on Crowdfunding Platforms

Aravinda Garimella, University of Washington, Foster School of Business, Mackenzie 350, Seattle, WA, 98105, United States

Backers of crowdfunding projects are heterogeneous in market knowledge, sophistication and overall informedness. We examine the roles of informed and uninformed backers on reward-based crowdfunding platforms. Using transaction-level data from a leading Chinese crowdfunding platform, we classify backers into informed and uninformed backers based on their contribution patterns. We study how uninformed backers affect fundraising dynamics and the ultimate performance of crowdfunding projects. Drawing from theoretical models of investor sentiment, we offer findings with important implications for crowdfunding platforms and entrepreneurs.

##### 4 - Is Non-persistent Social Status a More Useful Incentive Mechanism? Evidence from Yelp Elite Squad

Mingyue Zhang, Beijing Foreign Studies University, Beijing, China, Xuan Wei

Content sharing platforms such as product review websites largely depend on users' voluntary contributions. To motivate the contributions, many platforms established reputation-based incentive mechanisms. Yet most of the existing research has focused on reputations that are everlasting. In this research, we study the effect of non-persistent social status on user behavior using data from Yelp Elite Squad which is a yearly program. We design fixed effect model as well as matching method to empirically study the effect of non-persistent social status on user's behavior in both short term and long term. Our study has significant implications for business models that rely on user contributions.

##### 5 - Do You Donate Out of Altruism or Self-interest? A Case of Conditional Social Gift Exchange in Fundraising

Cenyang Yang, University of Texas at Austin, Austin, TX, 78703, United States, Shun-Yang Lee, Andrew B. Whinston

In this paper we explore the motivation, altruism or self-interest, behind donation in the context of social gift. We tease out one's altruistic motivation from the self-interest motivation by introducing different levels of recommended donation amount through a randomized experiment. The results show that people behave selfishly when a social gift is incorporated in a more altruistic context, but altruistically when it is incorporated in a more self-interest context.



## ■ MC68

West Bldg 105C

### Data-driven Approaches to Predictive Analytics under Uncertainty

Sponsored: Quality, Statistics and Reliability

Sponsored Session

Chair: Abdallah A. Chehade, University of Michigan-Dearborn, Dearborn, MI, 48128, United States

#### 1 - Sensor Fusion via Statistical Hypothesis Testing for Prognosis and Condition Monitoring

Abdallah A. Chehade, University of Michigan-Dearborn, 4901 Evergreen Road, 2280 HPEC, Dearborn, MI, 48128, United States

The rapid development of sensing technologies made multiple sensors available to real-time monitor the degradation status of machine systems. However, almost no method provides a statistical metric to evaluate the quality of degradation signals for prognosis and condition monitoring. To fill this literature gap, the paper constructs a health index via a sensor fusion framework for prognosis and degradation analysis through a series of statistical hypothesis tests. The performance of the proposed is evaluated and compared to benchmark methods on a publish C-MAPPS dataset.

#### 2 - Data-Driven Sensitivity Indices for Models with Dependent Inputs using the Polynomial Chaos Expansion

Zhanlin Liu, University of Washington, Seattle, WA, United States

Variance-based sensitivity analysis characterizes how the variance of a model output is propagated from the model inputs. Conducting such analysis for models with dependent inputs requires strong assumptions in the literature. We propose data-driven sensitivity indices for models with dependent inputs using the polynomial chaos expansion where the strong assumptions are not required. Two numerical examples, in which sensitivity indices cannot be directly obtained by the existing methods, are used to validate our proposed method.

#### 3 - Sensitivity Analysis on a Network using the Polynomial Chaos Expansion

Zhanlin Liu, University of Washington, 8033A 45th Ave NE, Seattle, WA, United States

Network structures exist in various engineering applications. Conducting variance-based sensitivity analysis on a network helps to control the quality of the network output. We propose the network sensitivity indices based on the sparse network polynomial chaos expansion to measure the sensitivity indices for the controllable independent inputs to the network output. The proposed method is more computationally efficient and requires fewer observations of the inputs and the output than using the Monte Carlo method. Two manufacturing examples are implemented to validate the proposed method.

## ■ MC69

West Bldg 106A

### High-Dimensional Data Analysis for System Prognostics and Performance Improvement

Sponsored: Quality, Statistics and Reliability

Sponsored Session

Chair: Xiaolei Fang, Georgia Institute of Technology, Atlanta, GA, 30329, United States

#### 1 - Reliability Analysis of Repairable Systems with Dynamic Covariate Information

Wujun Si, Wichita State University, 11316 E. Pine Meadow Ct, Wichita, KS, 67206, United States, Qingyu Yang

With the advancement of sensing technology, dynamic covariate information is often recorded simultaneously with reliability data. We propose a novel reliability model for repairable systems when dynamic covariate information is presented. A maximum likelihood estimation method is developed to estimate the model parameters. A simulation study is implemented to illustrate the developed methods, and a real world case study is conducted to demonstrate the proposed model.

#### 2 - A Prognostic Framework for Complex Engineering Systems with Multi-failure Modes

Liexiao Ding, Georgia Institute of Technology, Atlanta, GA, United States, Xiaolei Fang, Nagi Gebraeel

Many systems and subsystems usually have more than one cause of failure. Therefore, in real world applications, it is important to distinguish between these different causes of failures also known as Multi-failure Modes. To address the challenges, we develop a prognostic methodology, utilizing multi-sensor stream, to identify failure mode and then predict remaining useful life(RUL) of partially degraded systems. We propose a finite mixture of (log)-location-scale regression to model inhomogeneous sensor streams a grouped-penalized maximum likelihood estimator to perform sensor selection.

#### 3 - A Feature Ranking Method for Process Data Based on Distance Correlation

Andi Wang, Georgia Institute of Technology, H. Milton Stewart School of, Industrial and Systems Engineering, Atlanta, GA, United States, Juan Du, Xi Zhang, Jianjun Shi

In advanced manufacturing systems, multiple features are extracted from the data obtained from each working stage to characterize the process condition. Some of the features relate to the quality of the final products, and may provide valuable information on the quality of the product before inspection. Based on distance correlation metric, we propose a method that ranks the importance of the features obtained from the process based on their general dependency with the product quality. Theoretical properties of our method is studied, and a real case study in a solar cell manufacturing process validates the effectiveness of our method.

#### 4 - A Supervised Dimension Reduction-Based Prognostics Model for Applications with Incomplete Signals and Censored Failure Times

Xiaolei Fang, Georgia Institute of Technology, Atlanta, GA, 30329, United States, Kamran Paynabar, Nagi Gebraeel, Weijun Xie

The incompleteness of degradation signals and censoring of historical failure times pose significant challenges for prognostics. To address these challenges, this paper develops a novel method that combines a feature extraction term and a regression term. The first term is capable of extracting features using multi-stream incomplete signals, while the second term regresses the features against censored failure times. By simultaneously optimizing the two terms, the extracted features are guaranteed to be most informative for predicting failure times. To solve the optimization problem, a Block Prox-Linear Coordinate Descent algorithm with a global convergence property is developed.

## ■ MC70

West Bldg 106B

### New Advanced Deployment Features of Modeling Languages for Optimization

Sponsored: Computing

Sponsored Session

Chair: Bjarni Kristjansson, Maximal Software Inc., Arlington, VA, 22201, United States

#### 1 - Optimizing in the Cloud - Deploying Optimization Models on the Cloud with Web Services REST API's

Bjarni Kristjansson, Maximal Software Inc., 2111 Wilson Boulevard, Suite 700, Arlington, VA, 22201, United States

Over the past decade the IT has been moving steadfastly towards utilizing software on clouds using Web Services REST API's. In this presentation we will demonstrate the new MPL REST Server, which allows optimization models to be easily deployed on the cloud. By delivering optimization through a standard REST API, which accepts data in JSON and NoSQL formats, the optimization becomes purely data-driven. Client applications can now be implemented relatively easily on different client platforms such as mobile/tablets or web sites, using just standard HTML/CSS with Javascript, or any other preferred programming language.

#### 2 - New Programming Tools and Interfaces for Deploying AMPL Models

Robert Fourer, AMPL Optimization Inc., 2521 Asbury Ave, Evanston, IL, 60201, United States, Filipe Brandão

Though fundamentally declarative in design, optimization modeling languages are invariably implemented within larger modeling systems that provide a variety of programming options. Although programming is not used to describe models, it facilitates the integration of models into broader algorithmic schemes and business applications. This presentation surveys ways in which a programming interface can be useful for development and deployment, with examples from the AMPL modeling language and system. The focus is on new APIs (application programming interfaces) for controlling AMPL from programs in Python and in R, and on new facilities for invoking Python programs from within AMPL.

#### 3 - Enhanced Model Deployment and Solution in GAMS

Steven P. Dirkse, GAMS Development Corporation, Washington, DC, United States, Fred Fiand

The new capabilities recently added to GAMS make it easier than ever to develop, solve, and deploy models in non-traditional and powerful ways. Our cross-platform GAMS Studio provides a fresh look that will be welcomed by Mac users. Our embedded Python facility opens up a wealth of possibilities and makes data movement between GAMS and Python fast and painless, while providing a seamless union of Python code in a GAMS model. Finally, we have multiple ways to solve & deploy models to take advantage of parallel computing and opportunities to solve a group of similar models with only a single model generation. In this talk, we'll introduce these capabilities and demonstrate their use with a series of examples.

#### 4 - Xpress Mosel: Using Alternative Solvers and Trends in Modeling

Susanne Heipcke, FICO, 181 Metro Dr, Ste 700, San Jose, CA, 92130, United States

The modeling and solving environment Xpress Mosel has recently been turned into free software, simultaneously opening the Mosel language to alternative Mathematical Programming solvers. We give an overview of these solver interfaces and their use. The easy deployment of Mosel models as web applications without programming by adding configuration information to the model has raised demand for interconnection with analytics tools, such as Python. Another trend, the increasing use of Mosel for non-optimization tasks, has triggered a revision of the language, introducing a host of new programming-related features.

## ■ MC71

West Bldg 106C

### Joint Session ICS/Practice Curated: Retail Layout and Shelf Space Analytics

Sponsored: Computing

Sponsored Session

Chair: Ahmed Ghoniem, University of Massachusetts Amherst, Amherst, MA, 01003, United States

#### 1 - Discrete Event Simulation Model for Purchases at Temporary Displays in a Grocery Store

Alice E. Smith, Auburn University, 3301 Shelby Center, Dept of Industrial/Sys Engineering, Auburn, AL, 36849, United States, Ilknur Uludag

We develop a discrete event simulation model that evaluates impulse purchase likelihoods of product categories at temporary displays in grocery stores considering cross-category sales and customer paths. End-of aisles and islands are temporary displays for promotional, new, and high impulse products. In the simulation model, a customer shopping trip is created based on the number of purchased product categories, and a modified shortest path of the purchased products. The shopping basket data from a major grocery store chain, the impulse purchase likelihoods of product categories, and the permanent displays of product categories in a grid store layout are analyzed by the simulation.

#### 2 - Analytics for Store-wide Shelf Space Management

Bacel Maddah, American University of Beirut, Bechtel 519A, P.O. Box 11-0236 Riad El Solh, Beirut, 1107 2020, Lebanon, Ahmed Ghoniem, Tulay Flamand

We investigate how the allocation of product categories can be optimized in a fashion that guides in-store traffic and stimulates impulse buying. We develop a predictive regression model that estimates traffic densities at a shelf as a function of the shelf space allocation and the location of the shelf in the store. This traffic model is embedded within a mixed-integer nonlinear program that determines the location and the shelf space of all product categories in the store in a way that maximizes impulse buying. To overcome the computational challenges, we utilize a variable neighborhood search. We apply our analytics framework to a grocery store in Beirut with encouraging results.

#### 3 - Joint Consideration of Rack Layout and Product Allocation to Maximize Retail Impulse Purchase

Pratik J. Parikh, Wright State University, 3640 Colonel Gelnn Highway, 207 Russ Engineering Center, Dayton, OH, 45435-0001, United States, Bradley R. Guthrie

In a retail store, the configuration of racks and the placement of products on it affect what shoppers see during their shopping trip, and the eventual decision to buy. While research has shown that staple products (e.g., bread, milk) will be purchased no matter their location, the location of impulse products (e.g., candy, novelties) has a significant impact on their sales. We extend our prior research on quantifying exposure by proposing an optimization approach that determines the optimal rack orientation and curvature to maximize expected impulse profit across a variety of product location-allocation decisions.

#### 4 - Hierarchical Optimization for Retail Store Layout Design

Tulay Flamand, Colorado School of Mines, Division of Economics and Business, Engineering Hall 816 15th Street, Room 313, Golden, CO, 80401, United States, Ahmed Ghoniem, Bacel Maddah

We address a layout design problem for a retail department store by proposing a hierarchical approach. First, we formulate a mixed-integer programming model, which allocates departments to different areas of the store in a way that jointly maximizes the customers' shopping convenience and impulse buying. Using the prescribed allocation, we then propose a predictive model to form a main walkway around each department based on its traffic. Finally, we formulate a second optimization model that determines the specific location of each department category in its assigned area by considering the interplay between the category allocation, in-store traffic and impulse buying.

#### 5 - The Price-setting Newsvendor with Poisson Demand

Anna-Lena Sachs, University of Cologne, Albertus-Magnus-Platz, Cologne, 50923, Germany, Benedikt Schulte

We study the price-setting newsvendor with Poisson demand. We develop an analytical solution approach that covers a broad class of demand curves, including both linear and iso-elastic demand curves, explain how to apply our approach to more general demand functions via piece-wise linear approximation, and develop analytical and numerical insights. We characterize the behavior of the optimal price and analyze the performance gap of different price-setting heuristics. We observe instances in which a significant share of profits would be lost if the discrete nature of demand were not modeled explicitly.

## ■ MC72

West Bldg 211A

### KINFORMS

Sponsored: INFORMS Special Sessions

Sponsored Session

Chair: Chang Won Lee, Hanyang University, School of Business, 17 Haengdang Dong, Seoul, 133-791, Korea, Republic of

#### 1 - An Event Study of Servitization: Focusing on Korean Companies

Chongwoo Park, Korea University Business School, Seoul, Korea, Republic of, Hosun Rhim

Korean economy has been grown up based on the solid manufacturing industries. As the economy gets mature servitization is regarded as a breakthrough. We examine impact of servitization to the shareholder value by measuring the stock market reaction associated with servitization announcement.

#### 2 - A WoS-based Literature Review on Newsvendor Models

Sungyong Choi, Yonsei University, College of Government and Business, 1 Yoneseidae-gil, Wonju, 26493, Korea, Republic of

The newsvendor model has been actively studied in the field of management science and operations management as a stochastic inventory optimization model. Since the seminal work of Arrow et al. (1951), some variations of the newsvendor models have also been studied in literature until now. Then, using WoS (Web of Science), we will review the previous studies on the newsvendor models focusing on some well-known review papers and try to find further research directions.

#### 3 - Forecasting Aviation Services Delay using MIT Lincoln Lab and EuroControl's Estimation Criteria

Chang Won Lee, Hanyang University, School of Business, 17 Haengdang Dong, Seoul, 133-791, Korea, Republic of, Jae Sun Jeong

This study is to forecast aviation services delay by aviation weather. This study developed a forecasting model of the delayed cost of aviation service caused by aviation weather. We use the delay reduction model by MIT Lincoln Lab and EuroControl's estimation criteria for delay cost

#### 4 - A DEA-AR Model with Weight Bounds Based on Triangular Distributions

Sangwon Eum, Korea University Business School, Seoul, Korea, Republic of, Hosun Rhim

We propose a DEA-AR model using stochastic weight bounds. For practical purpose, triangular distribution is assumed. We test the model by changing parameters of the distribution. Real data set is used for the test.

## ■ MC73

West Bldg 211B

### JFIG Panel Discussion: Tips for Successful Publication from Journal Editors

Sponsored: Junior Faculty JFIG

Sponsored Session

Chair: Anahita Khojandi, University of Tennessee, Knoxville, TN, 37996, United States

#### 1 - JFIG Panel Discussion: Tips for Successful Publication from Journal Editors

Anahita Khojandi, University of Tennessee, 521 Tickle Building, Knoxville, TN, 37996, United States

Past and current editors from top journals will share tips on how to get your paper successfully published, from selecting the right journal to preparing and finalizing the manuscript.

#### Panelists

Joseph Geunes, Texas A&M University, College Station, TX, United States

Jianjun Shi, Georgia Institute of Technology, H. Milton Stewart School of, Industrial and Systems Eng, Atlanta, GA, 30332-0205, United States

Baris Ata, University of Chicago, Booth School of Busines, 5807 S. Woodlawn Ave, Chicago, IL, 60637, United States

Eva Lee, Georgia Tech, Industrial & Systems Engineering, Ctr for Operations Research in Medicine, Atlanta, GA, 30332-0205, United States

## ■ MC74

West Bldg 212A

### Preference-driven Decision Aiding I

Sponsored: Multiple Criteria Decision Making

Sponsored Session

Chair: Roman Slowinski, Poznan University of Technology, 60-965, Poland

Co-Chair: Adiel Teixeira De Almeida Filho, Universidade Federal de Pernambuco, Recife-PE, 50.630-971, Brazil

#### 1 - On Rationality Conditions for Multi-attributed Choice Behavior

Pekka J. Korhonen, Aalto University School of Business, Pahkinaranta 10, Huhmari, 03150, Finland, Jyrki Wallenius, Peng Xu, Tolga Genc

This paper deals with rationality conditions for choice behavior. We explore two different types of choice settings: (1) Win-Win setting, (2) Tradeoff setting. We study the decision-maker's rationality conditions in both settings. The key underlying theoretical assumptions in our paper are increasing and concave single-dimensional utility (value) functions with decreasing marginal values and the Kahneman-Tversky Prospect Theory model of choice with loss aversion. We use an empirical experiment to illustrate our considerations.

#### 2 - Shared Decision Making (SDM): A Preference-driven Approach to Medical Decision Making

Evangelos Triantaphyllou, Louisiana State University, Dept of Computer Science, 298 Coates Hall, Baton Rouge, LA, 70803, United States, Edouard Kujawski, Juri Yanase

A unique and important type of decision making occurs when a patient and clinicians collaborate to decide the best treatment. SDM is a fast emerging preference-driven approach. It aims at determining the treatment that best meets the personal values, goals and preferences of the patient. However, some SDM approaches may be seriously defective as they rely on erroneous models.

#### 3 - Evolutionary Multiobjective Optimization Guided by Preferences Modeled with Achievement Scalarizing Function

Roman Slowinski, Professor, Poznan University of Technology, Pl. Marii Skłodowskiej-Curie 5, NIP: 777-00-03-699, Poznan, 60-965, Poland, Tomasz Sternal

A new preference-driven interactive method is proposed that organizes the evolutionary search of multiobjective space along a set of directions indicated by a preference model consistent with some preference information elicited from the Decision Maker (DM). It is compared in a computational experiment to state-of-the-art multiobjective evolutionary optimization algorithms MOEA/D and NSGA-III. Our method applies an augmented Chebyshev function as a preference model. Adjusting the model parameters relies solely on a number of pairwise comparisons of some non-dominated solutions elicited from the DM during the algorithm run.

#### 4 - A New Online Tool to Comprehensively Support Multi-Criteria Decision Aiding Processes: ElectioVis

Maximiliano Ariel López, University of Buenos Aires, Buenos Aires, Argentina, Valentina Ferretti

This research proposes the development of a new online Multi-Criteria Decision Aiding tool that is able to support expert and non-expert users. It assists the method selection phase (i.e. choosing the best tool given the characteristics of the decision opportunity under analysis) as well as the model deployment (identifying the best solution for that specific decision). The interactive support provided by the ElectioVis online decision support system bridges insights from behavioural and normative theories to allow for the development of more successful interventions and solutions.

## ■ MC75

West Bldg 212B

### Joint Session MAS/Practice Curated: Analytic and Data Science Applications

Sponsored: Military and Security

Sponsored Session

Chair: Jon Alt, Naval Postgraduate School, Monterey, CA

Co-Chair: Eric Tollefson

#### 1 - Leveraging the Cloud Computing Environment to Support Decision Makers

Nathan I. Parker, TRADOC Analysis Center - Monterey, 700 Dyer Road, Room 178, Monterey, CA, 93943, United States, Jonathan Shockley

Here we use our ongoing effort to develop a cloud-hosted, browser interfaced decision support tool (DST), leveraging one of TRADOC Analysis Center's simulation models, as a starting point to discuss how cloud computing provides a unique capability to enable distributed data science applications. In addition to presenting the Logistics Battle Command DST itself, we will also discuss the underlying cloud infrastructure we employ and our development, test, and deployment pipeline.

#### 2 - Aerial Exposure Metric

James Jablonski, TRADOC Analysis Center, 1106 Leahy Rd, Monterey, CA, United States

The development of a method to calculate the level of exposure of each point in the sky in a given terrain box to points on the ground. The exposure metric can then be used to characterize the exposure of an area, to determine the optimal routing to minimize exposure in a given area, or to determine the optimal placement of air defense assets to maximize coverage in an area. The research also informs the computational costs of scaling these methods up to a larger terrain box and provides insights into future directions. A proof of principle application, developed using open source tools is provided.

#### 3 - Binary Classification with Asymmetric Error Type Control

Mathew Norton

We introduce a new formulation for binary classification with asymmetric error control inspired by the Neyman-Pearson (NP) paradigm. We propose a computationally efficient large margin classifier with the same generalization benefits as Support Vector Machines in high-dimensional feature spaces, but with fine tuned control over the amount of allowable Type I and Type II error. Our approach is based on a new characterization of uncertainty called Buffered Probability of Exceedance (bPOE) and, as consequence, often reduces to convex or linear programming.

#### 4 - A Methodological Framework for Developing a Defense Data Strategy

Kurt Klingensmith, TRAC, Monterey, CA, United States, Jon Alt

In order to lead the Army's modernization, the emerging Army Futures Command (AFC) will leverage timely, relevant, and credible analysis to inform and drive critical modernization strategies, priorities, and decisions. Achieving this requires the development and operationalization of a formal AFC Data Strategy. The Data Strategy envisions how the AFC will use data as an enterprise asset in support of modernization activities such as concept development, modernization planning, acquisition, and capability delivery. This presentation will present a systems architecting-based methodology for developing data strategies along with a framework for implementing and executing a data strategy.



### 5 - Reinforcement Learning Applications for Managing Public Sector “Use-or-Lose” Budgets

Erich Morman, Naval Postgraduate School, Monterey, CA, United States

When it comes to paying for contractor work, the private and public sectors operate under different environments. Regulatory constraints at the Department of Defense (DoD) as well as predominately throughout the public sector complicate the decision of how best to pay a contractor. In the public sector, it is often required to provide full funding for a project upfront. Furthermore, the funding provided has an expiration point whereby money that is not spent within a certain timeframe is taken away by a higher treasury or comptroller office. In this study, we look to use reinforcement learning algorithms to design efficient sequential payment strategies for contracted projects that can limit the amount of funding lost by the public sector customer.

## ■ MC76

West Bldg 212C

### MIF Early Career Award

Sponsored: Minority Issues

Sponsored Session

Chair: Julie Simmons Ivy, North Carolina State University, Raleigh, NC, 27695-7906, United States

#### 1- Opportunities and Challenges in Patient Service Personalization

Eduardo Perez, Texas State University, Roy F. Mitte Complex, 749 N. Comanche St., San Marcos, TX, 78666, United States

Patient service personalization provides new opportunities for health care systems in their pursuit of better patient outcomes and commitment to quality and safety. Much like the recent expansion of product customization, service personalization has been expanding lately due to a variety of factors including technological advances that allow for better service delivery and communication. Much of the existing research has viewed service variability as something negative that must be controlled. However, customer variability in service needs provides an opportunity to deliver more value for patients through personalization of services. This talk will examine patient service personalization and the design of systems for service customization. Starting with a review of current work, the talk will develop a framework for patient service personalization and service design, focusing on the concept of patient variability. Then the talk will include a description on how to use this concept to extract greater value from the transaction between the patient and the health care system. Based on the framework, the talk will then identify important directions for future research from both practice and academic viewpoints.

## ■ MC77

West Bldg 213A

### Joint Session PSOR/Practice Curated: Transportation Issues in Smart Cities

Sponsored: Public Sector OR

Sponsored Session

Chair: Leila Hajibabai, PhD, State University of New York, Stony Brook, NY, 11794, United States

#### 1 - Integrated Signal Timing and Traffic Metering Optimization in Connected Urban Transportation Networks

Ali Hajbabaie, Washington State University, Raleigh, WA, 99164-2910, United States, Rasool Mohebifard, S.M.A. Bin Al Islam

In this paper, we proposed a distributed mathematical optimization program that dynamically optimizes the traffic signal indications at intersections and at the same time finds the optimal number of vehicles that should enter the transportation network from its boundary gates to maximize the overall network performance. The solution technique has a model distributed predictive control structure that uses the location information of connected vehicles and vehicle counts from loop detectors to estimate the system state to optimize the decision variables. The results show that the proposed algorithm outperforms several benchmark solutions and increases the network throughput by 41.8% to 43.2%.

#### 2 - A Consensus-based Trajectory Control Logic for Connected and Autonomous Vehicles in a Signal-Free Intersection

Leila Hajibabai, State University of New York at Stony Brook, Department of Civil Engineering, 2433 Computer Science, Stony Brook, NY, 11794, United States, Amir Mirheli, Mehrdad Tajalli, Ali Hajibabai

This paper presents a distributed cooperative control logic to plan conflict-free trajectories for connected and autonomous vehicles (CAVs) in signal-free intersections. The problem is formulated into CAV-level mixed-integer non-linear programs (MINLPs) that minimize each vehicle's travel time and avoid near-crash conditions. To push CAV-level solutions towards global optimality, we develop a coordination scheme that shares vehicle states on location and speed over a prediction period and incorporates such information in each CAV's respective MINLP.

#### 3 - Scheduling of Heterogeneous Connected Automated Vehicles at a General Conflict Area

Xiaopeng Li, University of South Florida, 4202 E. Fowler Avenue, ENG 207, Tampa, FL, 33620, United States, Saeid Soleimaniamiri

A mixed integer programming (MIP) model is proposed to solve the joint optimization problem that simultaneously determine scheduling and trajectories of connected autonomous vehicles at a multi-conflict point considering heterogeneous vehicle headways and values of time. A novel dynamic programming based solution approach is proposed to obtain a near optimal solution. A set of numerical examples show that the model solutions can significantly increase the capacity of the conflict point and reduce both travel time and fuel consumption.

#### 4 - Community-engaged Operations Research as a Tool to Support Diversity, Equity and Inclusion in the Profession

Michael P. Johnson, University of Massachusetts Boston, Department of Public Policy & Public Aff, 100 Morrissey Boulevard, Boston, MA, 02125-3393, United States

OR/MS/analytics faces two important questions regarding diversity, equity and inclusion. First, what has the profession done to address important diversity-related social problems? Second, what can the profession do to meet diversity, equity and inclusion goals for INFORMS? In this talk I explain the unique role that community operational research and community-based operations research can play in enabling our profession to become more welcoming to members of diverse backgrounds, and to solving important social problems for which diversity is a critical component.

## ■ MC78

West Bldg 213B

### Radiation Treatment Planning Under Uncertainty

Sponsored: Public Sector OR

Sponsored Session

Chair: Gino J. Lim, University of Houston, TX, 77204, United States

Co-Chair: Azin Khabazian, University of Houston

#### 1 - Understanding Impacts of Radiobiological Parameters in Adaptive Radiation Treatment Planning under Uncertainty

Azin Khabazian, University of Houston, Houston, TX, 77057, United States, Gino J. Lim

To effectively treat a cancer patient with radiotherapy, an effective treatment strategy must be in place that considers dose delivery history and the patients' on-treatment biological changes. In this study, we seek to understand the importance of considering tumor shrinkage and proliferation during radiation treatment and how this affects the optimal prescribed dose in each fraction. We propose a stochastic sequential optimization structure under setup uncertainty of dose delivery that optimizes the dose in various fractions of an adaptive radiation therapy treatment plan by comparing the damage in tumor cells against the damage to the normal tissues volumetrically.

#### 2 - New DVH Formulation and First-order Interior-point Method for Inverse Planning

Hongcheng Liu, University of Florida, Gainesville, FL, 32611, United States

In radiotherapy treatment inverse planning, a commonly used quality measure is the dose-volume histograms (DVH). The exact mathematical formulation of DVHs involves binary variables and is therefore intrinsically nonconvex. In contrast, conventional convex surrogates for inverse planning entails non-trivial differences from an exact formulation and, thus, provide limited control over the DVHs. This work presents a new formulation that combines a novel folded concave penalty-based constraint and a new kurtosis-based criterion. Tailored to the new formulation is a first-order interior-point method. Outperformance in terms of doses-at-volume was achieved through the proposed scheme.

### 3 - Automated IMRT Treatment Planning using Expedited Constrained Hierarchical Optimization (echo): Algorithm Development and Clinical Implementation

Masoud Zarepisheh, Memorial Sloan Kettering, 485 Lexington Ave, #2039, New York, NY, 10017, United States, Linda Hong, Ying Zhou, Sovanlal Mukherjee, James G. Mechalakos, Margie A. Hunt, Joseph O. Deasy

This study automates IMRT treatment planning by formulating that as a hierarchical constrained optimization problem (also known as prioritized optimization). We introduce an idea to speed up the optimization process by sparsifying the influence matrix and then solving an extra unconstrained optimization problem to compensate for the inaccuracy caused by sparsity. The algorithm is equipped with an effective heuristic to handle DVH constraints. The algorithm has been implemented in the clinical environment and has been used to treat more than 300 patients in about 9 months.

### 4 - Optimization of Fractionated Radiotherapy Treatments under Dose Delivery Uncertainty

David Papp, North Carolina State University, Raleigh, NC, United States, Melissa R. Gaddy, Sercan Yildiz, Jan Unkelbach

Radiotherapy treatments are fractionated, meaning that the treatment is administered in several sessions, each delivering a small dose to the patient. In current clinical practice, the fractions are identical, but recent work has demonstrated that there is substantial benefit to be had from delivering different dose distributions in each fraction—a concept known as spatiotemporal fractionation. One concern about such treatments, however, is that they might be more susceptible to the various sources of uncertainty in dose delivery, such as patient positioning errors. In this talk, we investigate how the potential benefit from spatiotemporal fractionation is affected by uncertainty.

## Monday, 3:10PM - 4:00PM

### ■ Keynote- Monday

West Bldg 301AB

#### Keynote: Scaling Transportation Capacity in the Age of E-Commerce

Keynote Session

Chair: Georgia Perakis, Massachusetts Institute of Technology, Sloan School of Management, 100 Main Street Rm E62-565, Cambridge, MA, 02142-1347, United States

#### 1 - Scaling Transportation Capacity in the Age of E-Commerce Presenter

Russell Allgor, Amazon, Seattle, WA, United States

Even as Amazon experiences year-over-year growth in package volume, it's been able to speedup delivery times and shorten the time it takes between when an item is ordered and the moment that item arrives on a customer's doorstep. Amazon's fulfillment business - along with that of other online retailers - has increased the pressure on parcel delivery transportation capacity both in the US and overseas. Continuing to satisfy customers' needs will require more efficient use of existing networks and the creation of additional capacity for package sortation, line haul trucking, air freight, and last mile delivery. The challenge of designing a network that can meet these dynamic needs requires us to develop technical solutions implemented through design tools that incorporate the latest process innovations. There are both technical and organizational challenges in creating network design decisions, which involve inventory placement, facility operations, facility locations, network connections, and scheduling. While the technical challenges are at least partially met through solving large-scale combinatorial optimization problems, the organizational challenges require innovative mechanisms that motivate network-wide cooperation while also allowing decentralized, scalable operation.

### ■ Keynote – Monday

West Bldg 301D

#### Keynote: Stochastic Optimization, Statistical Modeling and Distributed Processing Applied to Energy Planning (IFORS Distinguished Lecture)

Keynote Session

#### 1 - Stochastic Optimization, Statistical Modeling and Distributed Processing Applied to Energy Planning

Mario Veiga Pereira, PSR, Praia de Botafogo 228, Rio de Janeiro, Brazil

The explosive growth of renewables has compounded the modeling challenges for investment and operational decisions in the energy area: (i) joint representation of hydro, wind, solar as a multivariate, multiscale stochastic process; (ii) solving the co-optimization of storage (hydro, batteries etc.), renewable-driven generation reserves and power transmission as a multistage nonconvex stochastic optimization; and (iii) because renewable integration benefits from regional interconnections (portfolio effect), probabilistic simulations are carried out for very large systems. In this talk, we show that these challenges can be successfully addressed by the combination of: new nonconvex stochastic optimization algorithms such as SDDiP; advanced geoprocessing and Bayesian networks; distributed computational and data management tools; and new optimization-centered programming languages such as Julia/JUMP. The application of these tools will be illustrated with real planning studies for the US Pacific Northwest and energy integration of South America.

### ■ Keynote – Monday

West Bldg 301C

#### Keynote: UPS George D. Smith Prize

Emerging Topic: Keynote

Emerging Topic Session

Chair: Robert Dell, Naval Postgraduate School, Monterey, CA, United States

#### 1 - Innovative Collaboration Between Industry and Academics to Meet Future Analytics Talent Requirements

Melissa R. Bowers, University of Tennessee-Knoxville, Statistics, Operations, & Management Science, Knoxville, TN, 37996, United States, Mike Galbreth, Bryan Noreen, Madeleine Beatty

In 2018, the Master of Science in Business Analytics in the Haslam College of Business at the University of Tennessee received the UPDS George D. Smith Prize. This award acknowledges our collaboration with industry partners and our success in preparing students to be effective practitioners in industry. In the spirit of the prize, this representation shares our experience in creating and maintaining the program. Key aspects of the program are its focus on real-world problems at nearly every touchpoint and a continuing interaction with industry. Students develop technical skills, business subject matter expertise, communication, teamwork, and leadership skills needed to impact decision making in practice.

## Monday, 4:30PM - 6:00PM

### ■ MD01

North Bldg 121A

#### Data Driven Optimization and Learning

Sponsored: Optimization/Optimization Under Uncertainty

Sponsored Session

Chair: Andrew Lim, National University of Singapore, Singapore, 119245, Singapore

#### 1 - When Can We Improve on Sample Average Approximation?

Edward James Anderson, University of Sydney, Discipline of Business Analytics, Room 487, Merewether Bld H04, Sydney, NSW 2006, Australia

We want to minimize the expected value of an objective function  $f(x,y)$  with a decision variable,  $x$  and a random variable  $Y$ , where we have  $N$  samples drawn from  $Y$ . The standard approach of sample average approximation simply minimizes the average value over the observed samples. We consider how to use information on the underlying distribution (e.g. that it has a continuous density). We also consider robust approaches that minimize the worst outcome achieved after a small change to the sample points or the weights applied to them. We explore this through looking at a univariate decision variable, and simple functions  $f$ . We demonstrate problems for which robustification makes the SAA solution worse.

## 2 - “Model-based Regularization” in a Context of Choice Modeling

Shanshan Huang, National University of Singapore, National University of Singapore, BIZ2 B1-01, Singapore, 117592, Singapore, Andrew Lim, Tong Wang

This work defines and explores the notion of “model-based regularization in the context of choice modeling. Regularization is an important tool from Machine Learning that is used to stabilize the solutions of regression problems when there is little data (relative to covariates). We take the more general view that regularization is simply a perturbation of a data-driven estimate towards a sensible default solution so as to remove “variance at the cost of some bias.

## 3 - Effective Scenarios in Multistage Distributionally Robust Stochastic Programs with Total Variation Distance

Guzin Bayraksan, The Ohio State University, 210 Baker Systems, 1971 Neil Avenue, Columbus, OH, 43210-1271, United States, Hamed Rahimian, Tito Homem-de-Mello

We consider multistage distributionally robust stochastic programs (DRSP) with a finite number of scenarios, where we use total variation distance to form conditional ambiguity set of distributions. We investigate the question of which scenarios have “effect on the optimal value of this multistage DRSP. To identify the effective scenarios, we conduct perturbation analysis with respect to a collection of scenarios being excluded and propose easy-to-check conditions for them. We explore the effectiveness for a scenario path as well as for a scenario conditional on the history of the stochastic process. Computational experiments illustrate the results on finance and environmental problems.

## 4 - Approximating the Gittins Index for High-dimensional Bayesian Bandits

Andrew Lim, National University of Singapore, 15 Kent Ridge Drive, Mochtar Riady Building, Singapore, 119245, Singapore, Michael Kim

While the optimal policy for the Gittins-Whittle formulation of the multi-armed bandit is fully characterized in terms of the Gittins index, these are notoriously difficult to compute for high dimensional Bayesian bandits. We develop a method for approximating the dynamics of the posterior using the Bayesian Central Limit Theorem and show how it can be used to approximate the Gittins index for high-dimensional Bayesian bandits. Comparisons of the Gittins-Whittle framework to Thompson sampling and the Upper Confidence Bound approach will be discussed, and applications of our approximation to Bayesian bandits where the rewards are mixtures will also be presented.

## ■ MD02

North Bldg 121B

### Robust Optimization with Varying Uncertainty

Sponsored: Optimization/Optimization Under Uncertainty

Sponsored Session

Chair: Kartikey Sharma, Northwestern University, Evanston, IL, 60208, United States

#### 1 - Robust Non-stationary Queueing Theory

Chaithanya Bandi, Kellogg School of Management, Northwestern University, 2001 Sheridan Rd, 566, Evanston, IL, 60208, United States

We consider the problem of obtaining delay bounds for queueing systems with time varying arrival and service rates. We formulate optimization problems that allow tractable calculation of bounds on the waiting time.

#### 2 - Optimization under Decision-dependent Uncertainty

Omid Nohadani, Northwestern University, 2145 Sheridan Road, Technological Institute M233, Evanston, IL, 60208-3119, United States, Kartikey Sharma

The efficacy of robust optimization spans a variety of settings with predetermined uncertainty sets. In many applications, uncertainties are affected by decisions and cannot be modeled with current frameworks. This talk takes a step towards generalizing robust optimization to problems with decision-dependent uncertainties, which we show are NP-complete. We introduce a class of uncertainty sets whose size depends on decisions, and proposed reformulations that improve upon alternative techniques. In addition, the proactive uncertainty control mitigates over conservatism of current approaches.

## 3 - Optimization under Connected Uncertainty

Kartikey Sharma, Northwestern University, Room C223. 2145 Sheridan Road, Evanston, IL, 60208, United States, Omid Nohadani

Robust optimization methods provide a tractable method to address uncertainties in optimization. Typically, the uncertainty models are prespecified. In problems spread across multiple time periods, however, the uncertainty may be influenced by the past. In this presentation, we leverage this influence by, what we call, connected uncertainty sets, where the set parameters at each period depend on previous realizations. To find optimal here-and-now solutions, we reformulate robust constraints for these connected uncertainty sets. We evaluate the performance of this framework on a knapsack problem with different levels and directions of past dependence.

## 4 - Mixed-integer Recourse via Prioritization

Yuan Yuan Guo, University of Michigan, 1205 Beal Avenue, Ann Arbor, MI, 48109, United States, Ruiwei Jiang

In this talk, we study the transmission expansion planning problem with prioritization (TEP-P), where we rank the candidate circuits by considering the uncertainty of development budget, electricity load, and renewable energy supply. We propose a two-stage robust TEP-P model and solve this problem by using the Benders' decomposition approach. We validate the performance of the proposed approach via case studies based on real-world wind power data.

## ■ MD03

North Bldg 121C

### TIMES Distinguished Speaker

Sponsored: Technology, Innovation Management & Entrepreneurship

Sponsored Session

Chair: Gulru F. Ozkan-Seely, University of Washington Bothell, University of Washington Bothell, bothell, WA, 98011, United States

#### 1 - Alpha Strategies: Sustained Advantage in Entrepreneurial and Established Firms

Karl Ulrich, University of Pennsylvania, Philadelphia, PA, United States

All innovation begins with some kind of disequilibrium, and may lead to supra-normal profits for the pioneering enterprise. However, all disequilibrium eventually fades. This talk links what we know about strategy, finance, and innovation into a framework for understanding sustained competitive advantage for innovating organizations, whether new entrants or incumbents. I also examine the evidence for the magnitude and duration of sustained profitability above the cost of capital in established public companies, and consider the extent to which such profits are the result of innovation.

## ■ MD04

North Bldg 122A

### Computational Integer Programming

Sponsored: Optimization/Integer and Discrete Optimization

Sponsored Session

Chair: Ezgi Karabulut, Georgia Tech, 2257 Burdett Avenue, Troy, NY, 12180-2406, United States

#### 2 - Using the Membership Linear Program and General Split Disjunctions to Approximate the Split Closure

Junghwan Kwak, Korea Advanced Institute of Science & Technology, Daejeon, Korea, Republic of, Sungsoo Park

Split cuts are widely used cutting planes to solve general mixed-integer linear programs (MILPs). The split closure has been computationally shown to provide strong bounds for the optimal solutions of MILPs. To approximate the split closure, we generate rank-1 split cuts iteratively by applying general split disjunctions to the membership LP, which was used by Bonami (2012). Our algorithm can be carried out with any LP solver, without needing simplex tableau information. We study the properties of the membership LP (applied with general split disjunctions) and propose some practical strategies for improving the performance of the algorithm. Finally, we present detailed computational results.



### 3 - Enhanced Algorithms for Solving Biobjective Mixed Integer Programs

Ian Herszterg, Georgia Institute of Technology, 755 Ferst Dr, Atlanta, GA, 30318, United States, Diego Pecin, Natasha Boland, Tyler Perini, Martin Savelsbergh

We present fast and robust algorithms for solving biobjective mixed integer programs. The algorithms extend and merge ideas from two existing state of the art methods: the Boxed Line Method and the Epsilon-Tabu Method. We demonstrate their efficacy in an extensive computational study and demonstrate that they are capable of producing a high-quality approximation of the nondominated frontier in a fraction of the time required to produce the complete nondominated frontier.

### 4 - Decentralized Algorithms for Distributed Integer Programming Problems with a Coupling Knapsack Constraint

Ezgi Karabulut, Rensselaer Polytechnic Institute, Troy, NY, 12180-2406, United States, Shabbir Ahmed, George L. Nemhauser

Distributed optimization has been a trending topic in the recent years with the use of multiple processors to solve optimization problems. We are interested in optimizing discrete problems that use a common resource, namely integer programming problems coupled with a cardinality constraint. We focus our research on finding the optimal allocation of the resource in a decentralized way. Our distributed auction algorithm outputs an optimal allocation for problems that possess concavity property, with computational complexity of  $O(K)$ , where  $K$  is the amount of the resource. We further test the performance of the algorithm on problems without the optimality guarantee.

### 5 - Automatic Structure Detection in Mixed Integer Programs

Taghi Khaniyev, MIT Sloan School of Management, Cambridge, MA, United States, Matthew Galati, Samir Elhedhli

Bordered block diagonal structure in constraint matrices of integer programs lends itself to Dantzig-Wolfe decomposition. We introduce a new measure of goodness to capture desired features in such structures. We use it to propose a new approach to identify the best structure inherent in the constraint matrix. The main building block of the proposed approach is community detection which alleviates one major drawback of the existing approaches in the literature: predefining the number of blocks. When tested, the proposed algorithm was found to identify structures that lead to significant improvements both in computation time and optimality gap compared to those detected by the state-of-the-art.

## MD05

North Bldg 122B

### Special Session: Recent Advances in Conic Optimization

Sponsored: Optimization/Linear and Conic Optimization

Sponsored Session

Chair: Somayeh Moazeni, Stevens Institute of Technology, Stevens Institute of Technology, Hoboken, NJ, 07030, United States

#### 1 - Facial Reduction in Cone Optimization with Applications to Matrix Completions

Henry Wolkowicz, University of Waterloo, Faculty of Mathematics, Waterloo, ON, N2L 3G1, Canada

Strictly feasibility is at the heart of convex optimization. This is needed for optimality conditions, stability, and algorithmic development. New optimization modelling techniques and convex relaxations for hard nonconvex problems have shown that the loss of strict feasibility is a much more pronounced phenomenon than previously realized. These new developments suggest a reappraisal. We describe the various reasons for the loss of strict feasibility, whether due to poor modelling choices or (more interestingly) rich underlying structure, and describe ways to cope with it and, in particular, "take advantage of it".

## MD06

North Bldg 122C

### Joint Session OPT/Practice Curated: Theories and Applications of Nonconvex Quadratic Programming

Sponsored: Optimization/Global Optimization

Sponsored Session

Chair: Yiling Zhang, University of Michigan, Ann Arbor, MI, 48105, United States

#### 1 - Strong Formulations for Quadratic Optimization with M-matrices and Indicator Variables

Alper Atamturk, University of California-Berkeley, Industrial Eng. & Operations Research, 4141 Etcheverry Hall, MC 1777, Berkeley, CA, 94720-1777, United States, Andres Gomez

We study quadratic optimization with indicator variables and an M-matrix, i.e., a PSD matrix with non-positive off-diagonal entries. We prove that the minimization problem is solvable in polynomial time by showing its equivalence to a submodular minimization problem. To strengthen the formulation, we decompose the quadratic function into a sum of simple quadratic functions with at most two indicator variables each, and provide the convex-hull descriptions of these sets. We also describe strong conic quadratic valid inequalities. Computational experiments indicate that the proposed inequalities can substantially improve the strength of the continuous relaxations.

#### 2 - Strong Formulations for Conic Quadratic Optimization with Indicator Variables

Andres Gomez, University of Pittsburgh, Pittsburgh, PA, 15217, United States

We study the convex hull of a mixed-integer set given by a conic quadratic inequality and indicator variables. We provide the convex hull description of the set under consideration when the continuous variables are unbounded. We propose valid nonlinear inequalities for the bounded case, and show that they describe the convex hull for the two-variable case. All the proposed inequalities are described in the original space of variables and are SOCP-representable. We present computational experiments demonstrating the strength of the proposed formulations.

#### 3 - Exact Semidefinite Formulations for a Class of Random Nonconvex Quadratic Programs

Samuel Burer, University of Iowa, Dept Mgmt Sci/Tippie College of Business, S346 Pappajohn Business Building, Iowa City, IA, 52242-1000, United States, Yinyu Ye

We study a general class of random quadratically constrained quadratic programs (QCQPs), which has exact semidefinite relaxations with high probability as long as the number of variables is significantly larger than the number of constraints.

#### 4 - Ambiguous Chance-constrained Binary Programs under Mean-covariance Information

Yiling Zhang, University of Michigan, Ann Arbor, MI, 48105, United States, Ruiwei Jiang, Siqian Shen

We consider chance-constrained binary programs, where each row of inequalities that involve an uncertain technology matrix needs to be satisfied probabilistically. With the information of the mean and covariance matrix available, we solve distributionally robust chance-constrained binary programs (DCBP). Using two different ambiguity sets, we equivalently reformulate the DCBPs as 0-1 second-order cone (SOC) programs. We further utilize the submodularity of 0-1 SOC constraints and lifting to derive extended polymatroid inequalities. We incorporate the valid inequalities in a branch-and-cut algorithm for efficiently solving DCBPs. Finally, we demonstrate the computational efficacy.

## MD07

North Bldg 123

### Network Optimization and Graph Algorithms I

Sponsored: Optimization/Network Optimization

Sponsored Session

Chair: Bastian Matias Bahamondes, Universidad de Chile, Sur 1848 Maipu, Santiago, 9271708, Chile

#### 1 - A Fast Max Flow Algorithm

James B. Orlin, Massachusetts Institute of Technology, MIT E62-570, Cambridge, MA, 02139, United States, Xiaoyue Gong

In 2013, Orlin proved that the max flow problem could be solved in  $O(nm)$  time. For graphs with  $n$  nodes and  $m$  arcs, his algorithm ran in  $O(nm + m^{1.94})$  time, which is the fastest time for very sparse graphs. If the graph is not sufficiently sparse, the fastest running time was an algorithm due to King, Rao, and Tarjan [1994]. We describe a new variant of the excess scaling algorithm for the max flow problem. Its running time strictly dominates the running time of the algorithm by King, Rao, and Tarjan.

#### 2 - A Nested Cluster Ratio Cut for Divisive Hierarchical Clustering

Victoria Ellison, Duke University, Durham, NC, United States

Building upon the strengths of the minimum cluster ratio cut problem and hierarchical clustering algorithms, we propose an optimization-based divisive hierarchical clustering algorithm for networks, which we call the Nested Cluster Ratios Algorithm. This algorithm uses a proposed extension of the cluster ratio cut. We demonstrate this problem's hierarchical clustering property via its dual relationship with a modified uniform multicommodity flow problem. Finally, we give a parametric linear programming based heuristic for this algorithm and test performance on gene co-association networks.

**3 - An Empirical Investigation of Network Polarization**

Celso C. Ribeiro, Universidade Federal Fluminense,  
Rua Capistrano de Abreu 28, Apartment 702, Rio de Janeiro,  
22271-000, Brazil, Ruben Interian

New tools for evaluating the polarization of a network are presented. We depart from the definition of a new measure of node homophily and consider the homophily distribution over the nodes as an indicator of the strength of polarization. Next, to address the polarization of the network as a whole, a probabilistic approach is developed, providing a more insightful understanding of the status of the network. The usefulness of the approach is illustrated on real-life networks. Two graph optimization problems are formulated and explored to deal with the reduction of polarization: (1) the maximum-cardinality homophily reduction problem and (2) the minimum-cardinality balanced edge addition problem.

**4 - Supervalid Inequalities for Network Interdiction Problems**

Ningji Wei, PhD Candidate, University at Buffalo, SUNY,  
North Tonawanda, NY, United States, Jose Luis Walteros

We focus on attacker-defender network interdiction problems in which: 1) the objective minimizes the attacker's cost of achieving a fixed disruption level over the defender's problem; 2) the defender's problem is to select an optimal graph structure (e.g., a shortest path, a spanning tree) over the residual graph; 3) the attacker strategies are defined over the same ground set of the graph structures. e.g., if the structures are defined over the edges, the attacker also interdicts edges. We develop a cut-generating framework that produces a general class of supervalid inequalities that remove non-trivial suboptimal solutions. We show how to adapt our framework to tackle a wide variety of problems.

**5 - Routing and Wavelength Assignment for All-optical Networks: A Defender-attacker-operator Game**

Mehdi Hemmati, New Mexico State University, Las Cruces, NM,  
88011, United States, Cole Smith

All-optical Networks (AONs) form the foundation of Internet backbone. They transmit the data over light rays, which require dedicated wavelengths. Hence, the routing problem in AONs turns into the so-called Routing and Wavelength Assignment (RWA) problem. We discuss an extension of the RWA problem to study the resilience of AONs in the presence of intentional disruptions. We propose a multi-level integer program and investigate the solution techniques by studying the solution space of the related optimization problem.

**6 - Adaptivity in Network Interdiction**

Bastian Bahamondes, Universidad de Chile, Santiago, Chile,  
Jose Correa, Jannik Matuschke, Gianpaolo Oriolo

We study a network security game arising in the interdiction of fare evasion or smuggling. A defender places a security checkpoint in the network according to a chosen probability distribution over the links. An intruder, knowing this distribution, wants to travel from her initial location to a target node. For every traversed link she incurs a cost equal to its transit time, and if she encounters the checkpoint, she has to pay a fine. The intruder may adapt her path online, exploiting additional knowledge gained along the way. We study the complexity of computing optimal strategies for the intruder and defender and the worst-case ratio of the intruder's best adaptive to her best non-adaptive strategies.

**■ MD08**

North Bldg 124A

**Joint Session OPT/Practice Curated: Integer Programming for Network Optimization and Applications**

Sponsored: Optimization/Network Optimization

Sponsored Session

Chair: Ou Sun, University of Arizona, Tucson, AZ, 85719, United States

Co-Chair: Neng Fan, University of Arizona, Tucson, AZ, 85721, United States

**1 - Algorithms and Complexity Results for Routing Trains through a Railyard**

Kelly Sullivan, University of Arkansas, 4207 Bell Engineering  
Center, 1 University of Arkansas, Fayetteville, AR, 72701,  
United States, Negin Enayaty Ahangar

We consider the problem of identifying a shortest route for a locomotive pulling a cut of cars through a railyard network in which nodes correspond to switches and edges correspond to tracks. As compared to a traditional shortest path problem, this problem is challenging because the route must accommodate, subject to the geometry of the yard tracks, the length of the cut of cars plus the length of the locomotive at any time. We model this problem as an integer program, prove its NP-hardness, and propose a solution approach that is polynomial for an important special case.

**2 - Benders Cut-and-solve: A New Versatile Tool for Network Optimization**

Carlos Armando Zetina, Concordia University, CORS/INFORMS  
Montreal Operations Research Stu, 1455 de Maisonneuve  
Boulevard W, Montreal, QC, H3G 1M8, Canada, Ivan Contreras,  
Jean-Francois Cordeau

Cut-and-solve has been used to solve the TSP and facility location to optimality. This method can be thought of as a generalized local branching in which at each level of the enumeration tree only two child nodes exist, one corresponding to a smaller "sparse" problem and the other as its complement known as the "dense" problem. We propose the use of Benders-based branch-and-cut as the black box MIP solver for "sparse" problems. Two important advantages of this are the reduced problem size and the re-usability of the Benders cuts generated in previous iterations. We present promising computational results for a naive implementation used to solve the fixed-charge multicommodity network design problem.

**3 - Minimum Cost Vertex Blocker Clique Problem**

Farzaneh Nasirian, University of Massachusetts-Boston,  
100 William T. Morrissey Blvd, Boston, MA, 02125, United States,  
Foad Mahdavi Pajouh, Josephine Namayanja

This talk addresses the minimum cost vertex blocker clique problem (CVCP) in which we are interested in detecting a subset of vertices in a graph with a minimum blocking cost whose removal bounds the weight of any weighted clique in the remaining graph by a given  $\tau > 0$ . We propose new linear 0-1 programming formulations with the exponential number of constraints and a new set of facets for the CVCP polytope. We also develop the first combinatorial branch-and-bound algorithm to solve this problem. The computational performance of these exact algorithms is studied on a test-bed of randomly-generated and real-life graphs.

**4 - Manufacturing Processes with Renewable Energy Integration and Demand Response**

Jose Luis Ruiz Duarte, University of Arizona, 1127 E. James E.  
Rogers Way, Tucson, AZ, 85721, United States, Neng Fan

International efforts for CO2 reduction require the engagement of industry sector, as a major energy consumer in the world. The integration of renewable energy sources (RES) into manufacturing processes is an alternative. In this work, a mathematical programming model is developed to obtain the optimal production schedule considering consecutive processes, integration of both onsite and grid RES, onsite energy storage systems, and demand response policies. Robust formulation approach is used to obtain optimal operations under the worst-case scenario for RES generation. A solution algorithm is developed to solve this formulation and is validated by numerical experiments

**5 - A Stochastic Mixed Integer Programming for GIS-based Biorefinery Facility Location Problem**

Ou Sun, University of Arizona, 827 E. Drachman Street, Tucson,  
AZ, 85719, United States, Neng Fan

A typical biomass supply chain consists of the following five components: harvesting and collection, storage, pretreatment, transportation, and conversion. Facility location problem is embedded in and vital to both pretreatment, and conversion processes. Geographic information system (GIS) is widely used to decide the facility locations with consideration of different related factors. Due to the special characteristics of biomass, the harvest yield is uncertain, which leads to the uncertainties through the whole supply chain. We take uncertainties into consideration and formulate a stochastic mixed integer programming by utilizing GIS tools for biorefinery facility location problem.

**■ MD09**

North Bldg 124B

**Methods for Large Scale Nonlinear and Stochastic Optimization II**

Sponsored: Optimization/Nonlinear Programming

Sponsored Session

Chair: Albert Solomon Berahas, Evanston, IL, 60208, United States

Co-Chair: Francisco Jara-Moroni, Northwestern University,  
Evanston, IL, 60208, United States

**1 - A Stochastic Line Search Method with Convergence Rate Analysis**

Katya Scheinberg, Lehigh University, 200 W. Packer Ave,  
Bethlehem, PA, 18015, United States, Courtney Paquette

For deterministic optimization, line-search methods augment algorithms by providing stability and improved efficiency. We adapt a classical backtracking Armijo line-search to the stochastic optimization setting. While traditional line-search relies on exact computations of the gradient and values of the objective function, this method assumes that these values are available up to some dynamically adjusted accuracy which holds with some sufficiently large, but fixed, probability. We show the expected number of iterations to reach a near stationary point matches the worst-case efficiency of typical first-order methods, for nonconvex convex and strongly convex objectives

**2 - Nonlinear Programming Reformulations of Chance Constraints**

Alejandra Peña-Ordieres, Northwestern University, Evanston, IL, United States, Andreas Waechter, Jim R. Luedtke

We present a new method for solving nonlinear continuous optimization problems with chance constraints. We introduce reformulations of the probabilistic constraints based on quantile functions and examine the theoretical and statistical guarantees of the approximation. To handle joint chance constraints, we propose an exact penalty function and use it to design an S1QP-type trust-region method. We demonstrate the efficiency of the method in numerical experiments.

**3 - A Unifying Scheme of Primal-dual Algorithms for Distributed Optimization**

Fatemeh Mansoori, Northwestern University, Evanston, IL, United States, Ermin Wei

We study the problem of minimizing a sum of local convex objective functions over a network of processors/agents. Many of the existing distributed algorithms with constant stepsize can only converge to a neighborhood of optimal solution. To circumvent this shortcoming, we propose to develop a class of distributed primal-dual algorithms based on augmented Lagrangian. To improve convergence speed, we design algorithms with multiple primal updates per iteration. We can show that such algorithms converge to the optimal solution under appropriate constant stepsize choices. The proposed class of algorithms can be extended to the general form of linearly-constrained convex optimization problems.

**4 - Applying Model-based Derivative Free Methods in Reinforcement Learning**

Liyuan Cao, Lehigh University, Bethlehem, PA, 18015, United States

Model-based derivative free methods are algorithms designed to optimize black-box functions. We use them in reinforcement learning, where the problems are modeled as black-box functions whose input is the set of parameters that define the policy, and the output is the reward. We test these methods in the OpenAI Gym environment and show that they are capable of learning high quality policies. Issues in the objective functions such as noise and non-smoothness are addressed. We compare our approach to recently proposed methods based on randomized finite differences and show connections between them.

**■ MD10**

North Bldg 125A

**Joint Session MSOM/Practice Curated: Commodity and Energy Operations**

Sponsored: Manufacturing & Service Oper Mgmt

Sponsored Session

Chair: Selvaprabu Nadarajah, University of Illinois at Chicago, 601 South Morgan Street., UH 2406, Chicago, IL, 60607, United States

Co-Chair: Nicola Secomandi, Carnegie Mellon University, Pittsburgh, PA, 15213, United States

**1 - Pathwise Optimization for Merchant Energy Production Modeled as a Switching Option**

Bo Yang, Carnegie Mellon University, Pittsburgh, PA, 15213, United States, Selvaprabu Nadarajah, Nicola Secomandi

Merchant energy production modeled as a switching option gives rise to an intractable Markov decision process (MDP). It is common to combine least-squares Monte Carlo (LSM) and information relaxation and duality techniques to compute a feasible operating policy and bounds on the optimal policy value for this MDP. We extend the less explored pathwise optimization (PO) approach for this purpose, developing preconditioning and decomposition methods to make the resulting linear program solvable. On realistic instances, PO leads to substantially better optimality gaps but requires longer run times than LSM, slightly improving on the near-optimal LSM based operating policies.

**2 - Analysis of Competitive Energy Markets under Capacitated Transportation**

Ian Yihang Zhu, University of Toronto, 144A, 60 Harbord Street, Toronto, ON, M5S3L1, Canada, John R. Birge, Timothy Chan, Michael Pavlin

This paper considers the interplay between the transportation network, market structure and equilibrium prices of energy markets. We derive analytical methods drawing on inverse optimization and clustering methods that allows us to obtain insights into market structure and integration using only easily available regional pricing data. We show through several case studies of the North American gasoline market how our methodology yields results that are consistent with the underlying transportation network and market structure.

**3 - Operations and Investment of Energy Storage in a Tree Network**

Owen Wu, Indiana University, Kelley School of Business, 1309 E. 10th Street, Bloomington, IN, 47405, United States, Roman Kapuscinski

Matching electricity supply with demand is challenging due to inherent variabilities in demand and renewable power generation. Energy storage, though expensive, is operationally beneficial to electricity systems. In this talk, we discuss the optimization of energy storage investment and operations. In particular, we consider the problem of siting (where to invest) and sizing (how much capacity to invest) storage facilities in a tree network that has one power generation node and many demand nodes. The objective is to minimize the total storage investment and long-run power generation costs. We provide new insights on the key factors that affect storage investment decisions and the total costs.

**4 - Managing Shutdown Decisions in Merchant Commodity and Energy Production: A Social Commerce Perspective**

Selvaprabu Nadarajah, College of Business, University of Illinois at Chicago, 601 South Morgan Street., UH 2406, Chicago, IL, 60607, United States, Alessio Trivella, Stein-Erik Fleten, Denis Mazieres, David Pisinger

Merchant commodity/energy production assets operate in markets with volatile prices and exchange rates. Plant closures often adversely affect the parent company and the local community. We study if mitigating these effects is financially viable by designing two types of policies that delay or avoid a plant closure. The first policy is grounded in anticipated regret theory and determined using approximate dynamic programming (ADP), while the second extends production margin-based heuristics used in practice and is computed using ADP and binary classification. Our operating policies significantly delay/avoid shutdowns for small asset value losses on real aluminum production instances.

**■ MD11**

North Bldg 125B

**Joint Session MSOM/Practice Curated: Finance and Risk Management Applications in OM**

Sponsored: Manufacturing & Service Oper Mgmt/iFORM

Sponsored Session

Chair: Yuan-Mao Kao, Duke University, Durham, NC, 27708, United States

Co-Chair: N. Bora Keskin, Duke University, Durham, NC, 27708-0120, United States

**1 - Government Financing for Clean Technology Development**

Seung Hwan Jung, Texas A&M University-Kingsville, 3118 La Rochelle Way, Corpus Christi, TX, 78414, United States, Lingxiu Dong

The goal of this paper is to study government financing for a firm's clean technology development under a financial constraint. In this paper, we investigate the impact of government financing on environment and the firm's bankruptcy risk when market uncertainty exists.

**2 - Operational Risk Management: Optimal Incentive Contract**

Yuqian Xu, University of Illinois at Urbana-Champaign, Wohlers Hall 487, 1206 S. 6th St, Champaign, IL, 61820, United States, Lingjiong Zhu, Michael L. Pinedo

In this paper, we study how a financial firm can offer incentive bonus contracts to its employees so as to incentivize them to exert efforts in reducing potential operational risk losses. Each employee then needs to balance the trade-off between the effort based bonus and the cost of the efforts to him or her (in a non-monetary form). We characterize the equilibrium strategy between the firm and its  $N$  employees, and then discuss the conditions under which incentive bonuses would be issued.

**3 - Comparison of Integrated Risk Management Frameworks for Newsvendors**

Panos Kouvelis

We study a newsvendor problem with profit risk control using VaR constraints. When a firm's demand correlates with the price of a tradable financial asset, both financial tools (derivatives) and operational tools (inventory) can be used for profit risk management. Such integrated risk management (IRM) approaches have been studied using various optimization frameworks to reflect the risk aversion of decision-makers. To the best of our knowledge, we are the first to study IRM in a newsvendor setting using profit maximization under VaR constraints (mean-VaR). We compare different IRM frameworks and find that only under mean-VaR, inventory and financial hedging decisions are separable.



#### 4 - Impact of Information Asymmetry and Limited Production Capacity on Business Interruption Insurance

Yuan-Mao Kao, Duke University, Durham, NC, 27708,  
United States, N. Bora Keskin, Kevin Shang

We study adverse selection and moral hazard issues that arise when an insurer offers business interruption insurance to a firm for guarding against disruption risks. The insurer cannot observe the firm's demand forecasts and recovery effort when a disruption occurs. We characterize the optimal insurance contracts to deal with the information asymmetry, and show how the firm's limited production capacity impacts the insurer's contract design. We also analyze the impact of ignoring the information asymmetry in designing insurance contracts.

## ■ MD12

North Bldg 126A

### Joint Session MSOM/Practice Curated: Choice Modeling and Applications in Retail Operations

Sponsored: Manufacturing & Service Oper Mgmt

Sponsored Session

Chair: Aydin Alptekinoglu, Pennsylvania State University, Pennsylvania State University, University Park, PA, 16802, United States

#### 1 - Product Line Design under Multinomial Logit Choices

Hongmin Li, Arizona State University, WP Carey School of Business, Dept of Supply Chain Management, Tempe, AZ, 85287, United States, Scott Webster, Gwangjae Yu

We study a product-line design problem in which customer choice among multiple products is given by a multinomial logit (MNL) model. A firm determines product attributes and prices in an evolving product line to maximize profit. In particular, given the prices and attributes of products that already exist in a product line, the firm optimizes prices and/or attributes of the new products to be added to the same product line.

#### 2 - Dynamic Pricing for Varying Assortments

Emily Mower, Harvard University, Cambridge, MA, United States, Kris Johnson Ferreira

Most multi-product demand learning and dynamic pricing algorithms learn product-specific demand parameters as opposed to attribute-specific demand parameters. We develop an attribute-specific learning-then-earning dynamic pricing algorithm geared for companies whose assortments change over time. To maximize efficiency in the learning phase, we incorporate methods from conjoint analysis and optimal experimental design. We test our algorithm in a randomized controlled field experiment at an e-commerce platform that sells excess inventory of fitness studio classes offered the following day.

#### 3 - Dynamic Choice and Consumption

John H. Semple, Southern Methodist University, Cox School of Business, 6212 Bishop Boulevard, Dallas, TX, 75205, United States, Aydin Alptekinoglu

We investigate the problem of purchasing a bundle of different (but substitutable) products for future consumption. We term this bundle an "n-pack. The optimal consumption of the pack can be analyzed using dynamic programming, which we use to derive the optimal policy and the structure of the value function for this multi-state problem. In some cases, the value function can be given in closed form, and thus our problem does not suffer from the usual curse of dimensionality.

#### 4 - A Comparative Empirical Study of Discrete Choice Models in Retail Operations

Gustavo J. Vulcano, Universidad Torcuato di Tella, Av Figueroa Alcorta 7350, Suite 405, Buenos Aires, 1428, Argentina, Gerardo Berbeglia, Agustin Garassino

In this paper, we conduct a systematic, empirical study of different demand models and estimation algorithms, spanning both maximum likelihood and least squares criteria. Through an exhaustive set of numerical experiments on synthetic and real data, we provide comparative statistics of the quality of different choice models and estimation methods, and characterize operational environments suitable for different model/estimation implementations.

## ■ MD13

North Bldg 126B

### Behavioral, Incentive and Policy Issues in Healthcare

Sponsored: Manufacturing & Service Oper Mgmt/Healthcare Operations

Sponsored Session

Chair: Tinglong Dai, Johns Hopkins University, Johns Hopkins University, Baltimore, MD, 21202, United States

Co-Chair: Ozlem Yildiz, University of Virginia, Charlottesville, VA, United States

#### 1 - Physician Peer Effects on Speed and Quality: Evidence from the Emergency Department

Raha Imanirad, Harvard Business School, Boston, MA, 02472, United States, Soroush Saghafian, Stephen J. Traub

In this study, we estimate peer effects in the context of an Emergency Department (ED) setting by addressing the question of whether peer physicians' characteristics including relative performance, experience, type of medical degree, and gender affect a physician's performance. Our findings provide strong evidence on the existence of peer effects in this setting. Our results have important practical implications for improving the operations of EDs. These include superior physician scheduling where one needs to decide which providers should be scheduled during the same shift as well as in physician training where one needs to provide guidance to physicians with ways to improve their performance.

#### 2 - Can Yardstick Competition Reduce Waiting Times?

Ozlem Yildiz, University of Virginia, Darden School of Business, 100 Darden Blvd. Darden School of Business., Office: FOB 189, Charlottesville, VA, 22903, United States, Nicos Savva, Tolga Tezcan

In this paper, we first show that the hospital reimbursement system currently used in practice does not incentivize hospitals to reduce waiting times. We then propose a modification which can achieve socially optimum investment without placing an onerous informational burden on hospital payers.

#### 3 - Conditions of Participation: Inducing Organ Discards and Patient Deaths on Transplant Waiting Lists?

Mohammad Delasay, Assistant Professor, Stony Brook University, Stony Brook, NY, United States, Sridhar R. Tayur

We investigate waiting list management from the viewpoint of a transplant center in the presence of the conditions of participation (COP). COP penalizes centers with lower-than-expected post-transplant survivals. We model the waiting list as a multi-dimensional queue, which we analyze by proposing accurate truncation bounds of its state space. Our experiments illustrate that a single COP threshold setting scheme across diverse transplant centers without consideration of transplant centers' specifications could induce cherry-picking of the candidates and offered organs. We discuss that COP lacks a net benefit approach by focusing only on post-transplant outcomes.

#### 4 - Optimal Sequencing of Diagnostic Tests for Differential Diagnosis

Simrita Singh, Northwestern University, Evanston, IL, United States, Sarang Deo, Sumit Kunnumkal

Motivated by the challenges of diagnosing TB from other respiratory illnesses, we consider the problem of optimal differential diagnosis: The decision maker has to identify the correct underlying condition in the patient by sequentially conducting imperfect diagnostic tests, each aimed at diagnosing a single condition. We model this problem as a stochastic dynamic program and obtain partial characterization of the optimal policy. We employ a novel data-driven implementation of information relaxation approach to construct a computationally efficient and tight upper bound. We also develop a policy improvement algorithm based on a greedy heuristic that yields near-optimal performance.

## ■ MD14

North Bldg 126C

### Joint Session MSOM/Practice Curated: Learning and Information Theory Applications in Queues

Sponsored: Manufacturing & Service Oper Mgmt/Service Operations

Sponsored Session

Chair: Nur Sunar, UNC, Chapel Hill, NC, 27517, United States

#### 1 - Reinforcement with Fading Memories

Kuang Xu, Stanford Graduate School of Business, 655 Knight Way, Stanford, CA, United States

We study the effect of imperfect memory on decision making in the context of a stochastic sequential action-reward problem. An agent chooses a sequence of actions which generate discrete rewards at different rates. She is allowed to make new choices at rate  $\gamma$ , while past rewards disappear from her memory at rate  $\delta$ . We provide closed-form formulae for the agent's steady-state choice distribution in the regime where the memory span is large ( $\gamma \gg \delta$ ), and show that the agent's success critically depends on how quickly she updates her choices relative to the speed of memory decay.

#### 2 - Signaling in Queues with Risk Averse Customers

Krishnamurthy Iyer, Cornell University, Ithaca, NY, 14850, United States, David Lingenbrink

We study revenue-optimal signaling in an unobservable queue offering service at a fixed-price to a Poisson arrival of customers, who decide to join or balk upon arrival. We focus on the setting where customers are strategic and risk-averse: a customer joins only if the sum of the mean of her waiting time and a multiple of its standard deviation is below a given threshold. Although the revelation principle no longer holds, a restricted form of the principle allows us to formulate an iterative approach to solve the information design problem, where each iteration involves optimizing a linear objective under quadratic constraints.

#### 3 - A Semi-parametric Bayesian Model for Call Center Arrivals

Kaan Kuzu, Univ of Wisconsin-Milwaukee, Sheldon B. Lubar School of Business, P.O. Box 742, Milwaukee, WI, 53201-0742, United States, Refik Soyer

We describe and analyze data for arrivals to a call center by presenting a modulated Poisson process model, which takes into account both covariate and time effects on the call volume intensity. We introduce a semi-parametric model and develop its Bayesian analysis to assess the effectiveness of different advertising strategies as well as to predict call arrival patterns. The proposed model and the methodology are implemented using real call center arrival data. We show that the proposed semi-parametric model has higher prediction accuracy than prior parametric models in literature.

#### 4 - Dynamic Learning and Rational Customers in Services

Nur Sunar, UNC, 1604 Village Crossing Drive, Chapel Hill, NC, 27517, United States, Yichen Tu, Serhan Ziya

We study a queueing system where customers can dynamically learn about a service feature. Our analysis shows that such rational customers can help the service provider boost its expected profit.

## ■ MD15

North Bldg 127A

### Joint Session MSOM/Practice Curated: Business Analytics

Sponsored: Manufacturing & Service Oper Mgmt/Service Operations

Sponsored Session

Chair: Han Ye, U. of Illinois at Urbana-Champaign, Champaign, IL, 61820, United States

Co-Chair: Haipeng Shen, Hong Kong

#### 1 - On the Accuracy of the Last-to-enter-service Announcement: Bridging Theory and Practice

Rouba Ibrahim, University College London, MS&I department, UCL, Gower Street, London, WC1E 6BT, United Kingdom, Achal Bassamboo

We propose a new, practice-driven, correlation-based framework to assess the relative accuracy of static and dynamic delay announcements. For a dynamic announcement, we consider the delay of the last customer to have entered service. Our approach combines queueing-theoretic analysis and an empirical study of real-life data.

#### 2 - Issue Resolution Estimation for Customer Service Centers

Han Ye, U. of Illinois at Urbana-Champaign, 350 Wohlers Hall, 1206 South Sixth Street, Champaign, IL, 61820, United States

Issue resolution estimation is critical for service center management. Traditionally, it is estimated via surveys and monitoring. In this paper, new models are developed to estimate issue resolution from operational data. The proposed models are then compared to existing practices under various scenarios. Performance grids of each studied model are constructed to provide practical guidelines on model selection.

#### 3 - Can Customer Arrival Rates Be Modelled by Sine Waves?

Donald Lee, Yale University, New Haven, CT, 06520, United States, Ningyuan Chen, Haipeng Shen

Customer arrival patterns typically exhibit strong seasonal effects. It is therefore natural to ask: Can a nonhomogeneous Poisson process (NHPP) with a rate that is the sum of sinusoids provide an adequate description of reality? We empirically investigate this question in two settings of interest to operations scholars: Arrivals to an emergency department and to a call centre. We develop novel estimation and testing procedures to show that the model is consistent with arrivals data from both settings. Our findings, combined with the flexibility and tractability of sinusoids, suggest that the NHPP with a sinusoidal rate function is a worthy workhorse model for time-varying arrival processes.

## ■ MD16

North Bldg 127B

### Socially Sustainable and Inclusive Operations

Sponsored: Manufacturing & Service Oper Mgmt/Sustainable Operations

Sponsored Session

Chair: Beril L. Toktay, Georgia Institute of Technology, Atlanta, GA, 30308, United States

#### 1 - Stable Schedules: A Win for Both Retail Associates and Stores

Saravanan Kesavan, University of North Carolina-Chapel Hill, Kenan-Flagler Business School, Cb 3490 Mccoll Building, Chapel Hill, NC, 27599-3490, United States

In this study at the Gap Inc., we run a large field experiment in 30 of their stores over a 10 month period to investigate the impact of improving schedule stability of 3000 part-time associates. We follow a randomized encouragement design to allow store managers to implement five interventions in the treatment stores. We document the increase in stability and its impact on sales, productivity, and turnover of employees.

#### 2 - Preventing the Cost of Over Development in China

Kwan Yu (Chris) Lo, The Hong Kong Polytechnic University, Hong Kong, Hong Kong, Yi Zhou, Christopher S. Tang

The low-cost sourcing strategy of international brands is one of the reasons of over-development in developing countries; the manufacturing firms in developing countries jeopardize society assets for the firms' economic benefits. We challenge if such short-term economic success could last in today's transparent global supply chain. Based on the environmental violations data of the listed manufacturing firms published by Institute of Public and Environmental Affair (IPE), we estimate the long-term impact of environmental violations, and identify the key predictors of environmental violations in China. We developed prediction models to identify high-risk firms before they pollute.

#### 3 - Optimal Seeding Policy under Rainfall Uncertainty

Ying Zhang, Clemson University, Clemson, SC, United States, Jayashankar M. Swaminathan

Increased agricultural productivity is often cited as a solution to the impending global food shortage problem. In this paper, we develop a model to determine the optimal seeding policy under rainfall uncertainty using a finite-horizon stochastic dynamic program. In our model, a farmer needs to decide whether to plant a seed in each period given the soil moisture. We show that the optimal policy is a time-dependent threshold-type policy where the farmer should plant when the seed amount on hand is above the optimal threshold. Utilizing field weather data from Southern Africa, we show significant yield advantage of the optimal schedule over commonly used heuristics.

#### 4 - Effects of Incentive Programs for Workplace Safety

Ravi Subramanian, Georgia Institute of Technology, 800 West Peachtree Street Nw, Scheller College of Business, Atlanta, GA, 30308, United States, Vinay Ramani

Using analytical models, we contrast the effects of contextual parameters on the occurrence and reporting of safety incidents under outcome-based and behavior-based incentive programs for workplace safety.

## ■ MD17

North Bldg 127C

**Global Supply Chain Management**

Sponsored: Manufacturing &amp; Service Oper Mgmt/Supply Chain

Sponsored Session

Chair: Lauren Xiaoyuan Lu, University of North Carolina at Chapel Hill  
- Kenan Flagler, Chapel Hill, NC, 27599, United States

**1 - Optimizing Local Content Requirements under Technology Gaps**

Lauren Xiaoyuan Lu, University of North Carolina at Chapel Hill -  
Kenan Flagler, Kenan-Flagler Business School, CB #3490, Mccoll  
Building 4701, Chapel Hill, NC, 27599, United States, Shiliang Cui

We study how the government of a developing country optimizes its Local Content Requirement (LCR) policy to maximize social welfare in a setting where foreign OEMs produce and sell multi-component products in the developing country. Due to technology gaps between local and global suppliers, local sourcing of components is more costly than global sourcing.

**2 - Dual Sourcing Inventory Management Over the Product Life Cycle**

Jan A. Van Mieghem, Northwestern University, Kellogg School of  
Mgmt, Evanston, IL, 60208-2009, United States, Jiankun Sun,  
Jason Acimovic, Douglas Thomas

We investigate dual sourcing inventory management policies, including the capped dual index policy, and their applications to the product life cycle.

**3 - Cover-up of Vehicle Defects: The Role of Regulator Investigation Announcement**

Woonam Hwang, HEC Paris, Jouy-en-Josas, 78350, France,  
Soo-Haeng Cho, Victor DeMiguel

Automakers such as Toyota and GM have been recently caught by the U.S. regulator deliberately hiding product defects in an attempt to avoid massive recalls. Interestingly, regulators in the U.S. and U.K. employ different policies in informing consumers about potential defects. To understand how the different announcement policies may affect cover-up decisions of automakers, we model the strategic interaction between a manufacturer and a regulator, and study whether and when the manufacturer has an incentive to cover up a potential defect. Based on our findings, we make four policy recommendations to help mitigate manufacturers' cover-ups.

**4 - Sourcing under the Supplier-auditor Collusion Risk**

Shiqing Yao, Monash University, Melbourne, Australia, Li Chen,  
Kaijie Zhu

Global brands are increasingly relying on third-party auditor to screen out low-quality suppliers. However, an unethical auditor may collude with a low-quality supplier to produce a false report. In this study, we investigate the buyer's equilibrium strategy in setting quality requirement under the risk of supplier-auditor collusion.

## ■ MD18

North Bldg 128A

**Joint Session BMI/Practice Curated: Empirical Research in Online Marketplaces**

Emerging Topic: Business Model Innovation

Emerging Topic Session

Chair: Yao Cui, Cornell University, Ithaca, NY, 14853, United States

**1 - Optimizing Services in Retail Networks using High-dimensional Panel Data**

Amandeep Singh, The Wharton School, 500 Jon M. Huntsman  
Hall, 3730 Walnut St., Philadelphia, PA, 19104, United States,  
Gad Allon, Ken Moon

We study how retail stores' multi-dimensional service levels affect consumers' buying behavior in a spatial setting. To this end, we propose the Double Block-Lasso BLP estimator, which combines the double selection procedure introduced in Belloni, Chernozhukov, and Hansen (2014), with demand estimation methods set forth in Berry, Levinsohn and Pakes (1995). Under mild assumptions of structural stability and sparsity, we obtain consistent estimates of the influences that retail stores exert across various spatial markets. Using the estimated influence structure, we highlight the service quality interventions promising greatest joint impact on consumers' buying patterns.

**2 - Consumer Preferences and System Design for Pooled Transportation**

Kashish Arora, INSEAD, Fontainebleau, France, Fanyin Zheng,  
Karan Girotra

In this study, we look at the drivers of the choice between non-demand cabs and a pre-determined and scheduled shuttle service. We use these to estimate the "inconvenience costs associated with shuttle platforms. Specifically, we estimate the inconvenience costs associated with walking to the shuttle, waiting for its arrival and traveling the extra distance on the shuttle. Secondly, we use the sensitivity estimates to design policy counterfactuals for determining the optimal size and frequency of the shuttle service and to suggest new routes for expansion

**3 - Impact of the Mobile Channel on Sales Concentration**

Fangyun Tan, Southern Methodist University, 6212 Bishop Blvd,  
Dallas, TX, 75275, United States, Nitish Jain

This study employs data from a large online apparel retailer, which operates both mobile and PC channels, to compare the causal effects of these two online channels on sales concentration, in terms of the share of popular products. We use a difference-in-differences estimation strategy that leverages a quasi-experiment stemming from the retailer's decision to discontinue its PC sales channel. We find that the mobile channel increases the share of popular products purchased by about 5% as compared with the PC channel. Furthermore, we find evidence which corroborates the role of a search cost led mechanism in driving the difference between the two channels' sales concentration level.

**4 - Tax-induced Inequalities in the Sharing Economy: Evidence from Airbnb**

Yao Cui, Cornell University, 401N Sage Hall, Ithaca, NY, 14853,  
United States, Andrew M. Davis

In this paper, we investigate the impact of occupancy tax on Airbnb listings.

## ■ MD19

North Bldg 128B

**Information and Networks**

Sponsored: Revenue Management &amp; Pricing

Sponsored Session

Chair: Kimon Drakopoulos, University of Southern California,  
Los Angeles, CA, 90066, United States

**1 - Platforms and Bloggers: Implications on Polarization and Learning**

Kimon Drakopoulos, University of Southern California, Los  
Angeles, CA, 90066, United States, Gad Allon, Vahideh Manshadi

In this paper we explore the implications of platform intervention and malicious bloggers on polarization and learning results.

**2 - Network Interactions and Social Value of Information**

Gowtham Tangirala, Columbia University, 3022 Broadway,  
4th Floor West, New York, NY, 10027, United States,  
Alireza Tahbaz-Salehi

We study decisions made by agents in a network with heterogeneous externalities under incomplete information. We consider an economy with one unknown fundamental and finitely many agents with quadratic payoffs and private, correlated information about the fundamental. We study how equilibrium welfare varies with commonality and precision of information. We find that it is possible for social welfare to exhibit a non-monotonic behavior with respect to commonality in efficient networks. We also find that under complementary (substitution) network effects, a more diffused (less diffused) network exhibits a higher social welfare.

**3 - Tampering with Information**

Odilon Camara, USC, Los Angeles, CA, United States,  
Ricardo Alonso

We study a game between a sender and a receiver, in which the sender can tamper with the information she provides to the receiver (falsify the results of an experiment). The receiver has access to some auditing technology to uncover tampering. We characterize the receiver's optimal auditing technology, taking into account how auditing affects the sender's equilibrium choice of information provision and tampering.



## ■ MD20

North Bldg 129A

### Learning and Platforms

Sponsored: Revenue Management & Pricing

Sponsored Session

Chair: Ramesh Johari, Stanford University, Stanford, CA, 94305-4121, United States

#### 1 - A Conditional Gradient Approach for Nonparametric Estimation of Mixing Distributions

Ashwin Venkataraman, Harvard University,  
Cambridge, MA, United States, Srikanth Jagabathula,  
Lakshminarayanan Subramanian

A key challenge in estimating mixture models is that the mixing distribution is often unknown and imposing apriori parametric assumptions can lead to model misspecification issues. We propose a new methodology for nonparametric estimation of the mixing distribution. We formulate the likelihood-based estimation problem as a constrained convex program and our key contribution is applying the conditional gradient (aka Frank-Wolfe) algorithm to solve this convex program, showing that it iteratively generates the support of the mixing distribution. We show that our estimator is robust to different ground-truth mixing distributions and outperforms the EM benchmark in two case studies on real data.

#### 2 - Bandit Learning with Positive Externalities

Virag Shah, Stanford University, Mail Code: 4026, Management  
Science and Engineering, Stanford, CA, 94305, United States,  
Jose Blanchet, Ramesh Johari

In many platforms the future user arrivals are likely to have preferences similar to users who were satisfied in the past. In other words, arrivals exhibit positive externalities. We study multiarmed bandit (MAB) problems with positive externalities. We show that the self-reinforcing preferences may lead standard benchmarks such as UCB to exhibit linear regret. We develop a new algorithm, Balanced Exploration, which explores arms carefully to avoid suboptimal convergence of arrivals before sufficient evidence is gathered, and an adaptive variant which successively eliminates suboptimal arms. We analyze their regret and establish optimality by showing that no algorithm can perform better.

#### 3 - Incentivizing Exploration by Heterogeneous Users

Peter Frazier, Cornell University, School of Operations Research,  
and Information Engineering, Ithaca, NY, 14853, United States,  
Bangrui Chen

We consider incentivizing exploration with heterogeneous agents. In this problem, bandit arms provide random attribute vectors from unknown fixed distributions over which agents have heterogeneous utilities. Selfish myopic agents arrive sequentially, observe past pulls, and pull the arm with the largest expected utility. Agents may be incentivized to pull underexplored arms through payments. We design an incentivization algorithm whose expected cumulative regret and payment are constant in the time horizon  $T$ , when agent types are finite and all arms are preferred by some agents. This contrasts with  $\log(T)$  regret in the standard MAB. Succinctly, heterogeneity provides free exploration.

#### 4 - Stochastic Bandits Robust to Adversarial Corruptions

Thodoris Lykouris, PhD Candidate, Cornell University,  
107 Hoy Road, Gates 336, Ithaca, NY, 14853, United States,  
Vahab Mirrokni, Renato Paes Leme

We introduce a new model of stochastic bandits with adversarial corruptions which captures settings where most of the input follows a stochastic pattern but a fraction of it is adversarially changed to trick the algorithm, e.g. click fraud, fake reviews, and email spam. The goal of this model is to encourage the design of bandit algorithms that (i) work well in mixed adversarial and stochastic models, and (ii) whose performance deteriorates gracefully as we move from fully stochastic to fully adversarial models. We provide an algorithm whose performance gracefully degrades with the total corruption the adversary injected in the data (while being agnostic to it) and a corresponding lower bound.

## ■ MD21

North Bldg 129B

### Data-driven and Machine Learning Research in Retail Management

Sponsored: Revenue Management & Pricing

Sponsored Session

Chair: Mehmet Gumus, McGill University, Montreal, QC, H3A 1G5, Canada

Co-Chair: Saibal Ray, McGill University, Montreal, QC, H3A 1G5, Canada

#### 1 - The Rise of Ship-to-store: Theoretical and Empirical Analyses of Its Impact on Online Sales

Necati Ertekin, Santa Clara University, Department of OM&IS,  
Leavey School of Business, Santa Clara, CA, 95053, United States,  
Mehmet Gumus, Mohammad Nikoofal

In this paper, we first develop a customer choice model to generate theoretical predictions regarding the impact of ship-to-store (STS) on online sales for two types of products, namely online-exclusive products (i.e., products available only online) and hybrid products (i.e., products available both online and offline), as well as on overall online sales. Next, we empirically test our predictions using data from an omnichannel retailer that launched STS at two different brand names. We find that, due to STS, online sales decrease at one brand name and increase at the other. We explain this controversy with our theoretical model and the extensive empirical analysis.

#### 2 - An Empirical Analysis of Intra Firm Product Substitutability in Fashion Retailing

Elcin Ergin, McGill University, 1001 Sherbrooke St W, Room 521,  
Montreal, QC, H3A 1G5, Canada, Mehmet Gumus, Nathan Yang

Our study investigates the impact of product shortages on sales in neighboring outlets using novel data from a fast fashion retailing chain. Our analysis reveals that sales for an item at a focal store increases when that same item experiences a stock out in neighboring store. We show that these product substitutability patterns across stores vary depending on the location type. We also demonstrate in a forecasting exercise that information about stock outs in neighboring outlets has value for prediction for certain periods of the product's life cycle. Finally, we investigate the revenue impact of making inventory allocation decisions using the neighboring outlets' stock out information.

#### 3 - Generating Realistic Customer Purchase Baskets Using Generative Adversarial Networks

Saibal Ray, McGill University, Desautels Faculty of Management,  
1001 Sherbrooke Street W, Montreal, QC, H3A 1G5, Canada,  
Thang Doan, Brian Keng

This project uses the purchase history from loyalty member card at the basket level (i.e., all items bought by a customer during a particular trip) for customers under the loyalty program of a chain drug store to develop a model that can generate realistic future "customer shopping list (basket) using the novel machine learning technique of Generative Adversarial Networks (GAN). Our first objective in this project is to find a representation/embedding of customers and the baskets they buy by analyzing the transaction histories. Once the above task has been accomplished, we will build a customer simulator that will generate realistic future customers and their purchase baskets for the next 4 weeks

#### 4 - Visual Listening In: Extracting Brand Image Portrayed on Social Media

Liu Liu, New York University, New York, NY, United States,  
Daria Dzyabura, Natalie Mizik

Images are on their way to surpassing text as the medium of choice for social conversations. In this paper, we propose a "visual listening in" approach to measuring how brands are portrayed on social media (Instagram), by mining visual content posted by users. We first train image classifiers of brand attributes via SVM and Convolutional neural networks. Then we apply the classifiers to brand-related images on social media. We study 56 brands in the apparel and beverages categories, and compare their portrayal in consumer-created images with images on the firm's official Instagram account, as well as with consumer brand perceptions measured in a national brand survey to derive managerial insights.

## ■ MD22

North Bldg 130

### Consumer Oriented Operations Models

Sponsored: Revenue Management & Pricing

Sponsored Session

Chair: Mingcheng Wei, University at Buffalo, Buffalo, NY, 14260, United States

#### 1 - Optimal Pricing in Online Marketplaces

Xuanming Su, University of Pennsylvania, The Wharton School,  
3730 Walnut Street, Philadelphia, PA, 19104, United States

We develop a pricing model for online marketplaces that match demand from customers with supply from firms. We consider prices between customers, firms, workers, and the marketplace, and then relate our results to current practice.

## 2 - When Prospect Theory Meets Consumer Choice Models: The Role of Reference Prices

Ruxian Wang, Johns Hopkins University, Carey Business School,  
100 International Dr, Baltimore, MD, 21202, United States

Reference prices arise as price expectations against which consumers evaluate products in their purchase scenarios. We investigate what will happen when prospect theory (e.g., reference prices) meets consumer choice models from the perspectives of both the consumers and the firm.

## 3 - Optimal Information Control Strategies for the Online P2P Platform

Shu Hu, Ningbo Supply Chain Innovation Institute China,  
Shiliang Cui, Mingcheng Wei

We investigate the optimal information control strategies for the online P2P platform, which will decide whether to provide product information for the buyer, and whether to provide market information for the seller, when it aims to maximize the average transaction volume and the average transaction amount, respectively. We further examine the value of product information for buyers and the value of market information for sellers.

## 4 - Dynamic Pricing of the Fixed-term Subscription Contracts or One-time Purchase Offered to the Strategic Customers in a Heterogeneous Market

Roozbeh Yousefi, Queen's University, 310 Bath Rd., Unit 1112,  
Kingston, ON, K7M9H1, Canada, Jue Wang, Yuri Levin,  
Mikhail Nediak

Subscriptions are agreements between a company which commits to deliver a service or provide access to a service and its customers. We present a continuous time dynamic pricing model for a monopolist offering a fixed term subscription contract without per-use charges and limit of access or a one-time purchase at all the instances, to strategic customers in a growing heterogeneous market. We modeled the discrete choice problem of customers and used it to formulate the monopolist's problem in terms of optimal control, derive its optimality conditions. We demonstrate the optimal pricing results in numerical experiments.

## 5 - Online Decision-making with High-dimensional Covariates and Binary Response

Wang Xue, Penn State University, Leonhard, Building, 310 S.  
Barnard St, University Park, PA, United States, Mingcheng Wei,  
Tao Yao

In this study, we consider the online learning and decision-making problem with high-dimensional covariates and binary response. We penalize the bandit model with Minimax Concave Penalty (MCP-bandit) to handle the high-dimensional issue. Under epsilon-decay sampling scheme, we show the cumulative regret of MCP-bandit is upper bound  $O(s^3 \log d \log T)$ , where  $s$  is the sparsity level,  $d$  is the total dimension and  $T$  is the time length. Moreover, we prove the  $\log T$  dependence of cumulative regret is optimal.

## MD23

North Bldg 131A

### Joint Session FSS/Practice Curated: Stochastic Games with Applications

Sponsored: Finance

Sponsored Session

Chair: Xin Guo, University of California-Berkeley, Piedmont, CA,  
94611, United States

#### 1 - A Stochastic Game and Moving Free Boundary Problem

Renyan Xu, University of California-Berkeley, 4141 Etcheverry  
Hall, OR Department, Berkeley, CA, 94720, United States,  
Xin Guo, Wenpin Tang

Stochastic control problems are closely related to free boundary problems, where both the underlying fully nonlinear PDEs and the separating boundaries are integral parts of the problems. In this talk, we propose a class of stochastic games and show how the free boundary problems involve moving boundaries due to the additional game nature. We will provide explicit solutions in terms of Nash equilibria by solving a Skorokhod problem with moving boundaries. We will use some special cases of the games in light of the classical finite fuel problem to compare game strategies in terms of pooling and sharing. We will also discuss the Nash equilibrium strategies in the framework of controlled ranked SDEs.

#### 2 - A Stochastic Numerical Method for Mean Field Games

Mathieu Lauriere, Princeton University, Princeton, NJ,  
United States

We present a new stochastic algorithm to solve mean field games and optimal control problems of McKean-Vlasov dynamics. This numerical method relies on the system of forward-backward stochastic differential equations characterizing the solutions to these problems. Several examples of applications will be provided. This is joint work with Ren Carmona.

## 3 - The Coordination of Centralized and Distributed Generation

Matteo Basei, University of California, Berkeley, Berkeley, CA,  
United States, Ren Aid, Huyen Pham

We analyse the interaction between centralised carbon-emissive technologies and distributed non-emissive technologies. A representative consumer can satisfy her electricity demand by investing in solar panels and by buying power from a centralised firm. We consider the point of view of the consumer, the firm and a social planner, formulating suitable McKean-Vlasov control problems with stochastic coefficients. First, we provide explicit formulas for the production strategies which minimise the costs. Then, we look for an equilibrium price.

## 4 - Non-zero Sum Stochastic Games with Impulse Control

Haoyang Cao, University of California, Berkeley, Berkeley, CA,  
United States

This is a joint work with Prof. Xin Guo and Mr. Matteo Basei. We generalize the single-agent impulse control problem, i.e. the cash management problem as in [Constantinides and Richard, 1978], to an N-player impulse game. In this impulse game, each agent controls its own state dynamics and they are coupled together through cost functions. We provide two versions of verification theorems, one requiring value functions to be continuous everywhere, the other relaxing the regularity condition and adding assumptions on cost structures instead. Under a symmetric setting, we are able to give a semi-explicit Nash equilibrium.

## MD24

North Bldg 131B

### E-Business

Sponsored: EBusiness

Sponsored Session

Chair: Cheng Nie, TX, United States

#### 1 - Does Money Talk? The Evidence from an Online Peer to Peer Car Sharing Platform

Yixin Lu, The George Washington University, 2201 G. Street NW,  
Funger Hall 506, Washington, DC, 20052, United States

We conduct a randomized field experiment at a large online peer-to-peer car sharing platform to examine the impact of monetary incentives on user onboarding. We find that monetary incentives are no better than simple email reminders in encouraging self-disclosure of private information nor user engagement with the platform.

#### 2 - Predicting Time to Upgrade Under Successive Product Generations

Xinxue Qu, Iowa State University, 4815 Todd Drive, 71, Ames, IA,  
50014, United States, Aslan Lotfi, Zhengrui Jiang

In the presence of successive product generations, customers may decide to purchase a future generation before its release. As a result, sales of the new generation often show a declining pattern. In this study, we propose an exponential-decay survival model to predict customers' time to upgrade decisions. Empirical analysis using data for a major sports video game series shows that the Expo-Decay model performs better in prediction accuracy. Empirical results reveal that previous adoption and usage habits impact upgrade decisions: (i) potential switching customers are more likely to upgrade; (ii) heavy players tend to upgrade earlier; (iii) specialized customers are less likely to upgrade.

#### 3 - Predicting Stock Price Movements via Multi-relational Inter-firm Networks

John Rios, University of Iowa, Iowa City, IA, United States,  
Kang Zhao, Nick Street

Predicting stock movements is challenging, but has attracted tremendous amount of attention from both practitioners and researchers. At the same time, firms interact with each other in a multi-relational network with multiple types of relationships. Using real-world supply and competition networks among more than 1,000 firms, we predict a firm's stock movements by leveraging performance of its customers, suppliers, and competitors. We show that features based on network neighbors of a firm significantly contribute to the prediction of its future stock movements. Additional analyses show that suppliers' and competitors' performance is more indicative of firms' stock movement than customers'

## ■ MD25

North Bldg 131C

### Best Student Paper Competition - II

Sponsored: Service Science

Sponsored Session

Chair: Aly Megahed, IBM Research - Almaden, San Jose, CA, 95123, United States

#### 1 - Service Science Best Student Paper Competition

Aly Megahed, IBM Research - Almaden, San Jose, CA, 95123, United States

This session consists of finalists presentations (judged by an expert panel) to determine the Best Student Paper Award for the Service Science Cluster.

## ■ MD26

North Bldg 132A

### Education Service

Sponsored: Service Science

Sponsored Session

Chair: Shari Weaver, Worcester Polytechnic Institute, 100 Institute Road, Worcester, MA, 01527, United States

#### 1 - Higher Education as a Service: Applying the Service Science Canvas Model to an International Undergraduate Program

Oleg V. Pavlov, Worcester Polytechnic Institute, SSPS, 100 Institute Rd., Worcester, MA, 01609, United States, Joan Lofgren, Frank Hoy

This article contributes to the understanding of higher education as a service by applying the service science framework to an academic program in northern Europe. We utilize the Service Science Canvas, which is a new tool that combines elements of the service science theory. The service science framework highlights unique features of the program such as the intensive curriculum, which promotes value co-creation among faculty and students. The framework also recognizes the importance of clear quality measures and effective governance due to the program's heavy reliance on visiting faculty.

#### 2 - Improving Volunteering in Non Profit Sector. Empirical Evidence from a Non Profit Organization in Education Sector in India

Sandeep Chitla, Indian School of Business, Hyderabad, 500111, India, Milind Sohoni, Arun Kumar Rout

Nonprofit Organizations (NPOs) typically face two critical challenges: (a) poor operational efficiency, and (b) inability to scale. We are working with a large NPO in the education sector in India to understand the challenges of hiring volunteers. We analyze demographic and behavioral characteristics of candidates who volunteered with the NPO in past. We also evaluate the efficacy of operational interventions done by NPO during the recruitment process.

#### 3 - Using the Service Science Canvas to Understand Institutional Change in a Public School System

Shari Weaver, Director, Teacher Preparation Program, Worcester Polytechnic Institute, 100 Institute Road, Worcester, MA, 01527, United States, Oleg Pavlov

Reforming STEM education in the United States continues to be a topic of active discussion and research. Why do some school districts succeed while others fail at implementing similar educational interventions? To answer this question, we apply the service science theory to characterize a PK-12 district that is viewed as a complex educational system. Our analysis utilizes the Service Science Canvas, which is a convenient methodological tool that includes common elements of the service science framework.

## ■ MD27

North Bldg 132B

### Integrating OR/MS/Analytics Scholarship and Teaching

Sponsored: Education (INFORMED)

Sponsored Session

Chair: Neil Desnoyers, Saint Joseph's University, Saint Joseph's University, Upper Darby, PA, 19082, United States

#### 1 - Master Scheduling in K-12 Education

Neil Desnoyers, Saint Joseph's University, 5600 City Avenue, Philadelphia, PA, 19131, United States, Rabia Ansari

For almost all those individuals who are tasked with performing it, the Master Scheduling process in K-12 education is painful. As one K-12 administrator

responsible for Master Scheduling in her school commented recently, "...it's a very daunting and time-consuming task." Significant advances in K-12 Master Scheduling have not occurred frequently. In fact, the last significant advance in the field ("block scheduling") was developed over 20 years ago. Improvements in data availability, scheduling algorithms, and programming languages since that time should change the landscape of the problem.

#### 2 - Research in the Classroom: Bridging the Gap at the Undergraduate Level

Ruben A. Mendoza, Saint Joseph's University, 5600 City Avenue, Philadelphia, PA, 19131, United States

Presenting academic research on Business Intelligence and Analytics to undergraduate students is difficult because the research can be too narrow or focused for undergraduates, require extensive familiarity with academic literature to interpret it correctly, or flat-out be too technical for the level of expertise (or interest) of the average undergraduate student. Finding accessible, current, and appropriate academic research that is pedagogically useful requires a very large investment of time and planning. How can academics find and learn to use practitioner-level research that is pedagogically and technically adequate to meet competing goals of rigor and accessibility?

#### 3 - A Projects Course to Prepare Undergrads for Analytics Careers

Michael H. Veatch, Gordon College, Department of Mathematics, 255 Grapevine Rd, Wenham, MA, 01984, United States

Mathematics undergraduates often lack some of the project and soft skills to help them enter analytics careers. We offer a course with semester-long industry projects using data analysis and O.R. The course has also led to some faculty-student research.

## ■ MD28

North Bldg 221A

### Railway Applications Section Interactive Session

Sponsored: Railway Applications

Sponsored Session

Chair: Kamalesh Somani, CSX Transportation, Jacksonville, FL, 32202, United States

#### 1 - Railway Applications Section Interactive Session

Kamalesh Somani, CSX Transportation, Jacksonville, FL, 32202, United States

Join us for an interactive look at the substantial use of advanced OR techniques in the railroad industry. Four major North American rail carriers (BNSF, CSX, NS, UP and Amtrak) will be onsite to give in-depth practical demonstrations of OR tools. Join us to learn how railroads implement robust solutions to complex business problems. The demonstrations will focus on the practical implementation of advanced OR models within companywide systems including the core software and technologies used, large scale data constraints, production level deployment, and business alignment.

## ■ MD29

North Bldg 221B

### Joint Session TSL/Practice Curated: Large-scale Data Analytics in Transportation System Modeling

Sponsored: TSL/Urban Transportation

Sponsored Session

Chair: Shanjia Zhu, George Mason University, Fairfax, VA, 22030, United States

Co-Chair: Sean Qian, Carnegie Mellon University, 5000 Forbes Ave, Pittsburgh, PA, 15213, United States

#### 1 - An Empirical Investigation of the Matching Technology in the Ride-sourcing Market

Daniel Vignon, University of Michigan, Ann Arbor, MI, United States, Zhengtian Xu, Yafeng Yin

With the rise in popularity of ride-sourcing services, ride-sourcing companies face challenges in meeting an ever growing demand. In order to answer these challenges, a deep understanding of the underlying mechanisms at play in the market is needed. For this purpose, we propose an empirical model of the ride-sourcing market, focusing especially on the matching technology. This model allows us to not only understand possible failure modes of the ride-sourcing market, but also how to remedy them.



## 2 - Inferring Multimodal Day-to-day Travel Dynamics using Smartphone App Data

Shanjiang Zhu, George Mason University, Nguyen Engineering Building, Suite 1300, 4400 University Drive Ms 6c1, Fairfax, VA, 22030, United States, Zhuo Yang, Guanqi Liu, Lei Zhang

This study investigates the day-to-day travel dynamics on a multi-modal network. Longitudinal travel trajectories data were collected using a smartphone app among commuters during Washington Metro Safetrack project. Algorithms were developed to infer the travel choices before, during, and after the network disruptions, which are crucial for assessing the impact of the unprecedented maintenance work at the Washington Metro. Findings from this study could help to inform agencies who are struggling with the aging infrastructure across the country and help them to develop better strategies.

## 3 - Early Warning Signal for Congested Large-scale Traffic Networks

Xiaozheng He, Rensselaer Polytechnic Institute, 110 8th St., JEC 4034, Troy, NY, 12180, United States, Chunhen Jiang, Jihui Nie, Jianxi Gao

This study proposes an early warning signal to indicate whether the traffic condition of a congested network is getting close to its critical degradation threshold, beyond which congestion is difficult to mitigate. The early warning signal is developed based on the critical slowing down theory for perturbed dynamical systems. Using the collected field data, we validate the proposed signal and show that the system recovery process becomes increasingly slow when the traffic condition approaches the critical point.

## 4 - Estimating Probability Density of Origin-destination Matrices on Congested Networks

Yudi Yang, 1420 Lake Boulevard, Apartment 17, Davis, CA, 95616, United States, Yueyue Fan, Johannes Royset

To understand the stochastic nature of travel demand is gaining more attention in transportation studies as reliability and resilience become important performance measures for transportation project evaluation. In this study, we aim to infer the probability density function (pdf) of Origin-Destination (O-D) demand variables by integrating (potentially) multiple data sources. Unlike most traditional statistical approaches that are only applicable to non-congested networks, the proposed method is designed to be capable of incorporating traffic network flow rules/models in a congested network and determining route choice proportion and O-D matrix simultaneously.

## 5 - Transportation Big Data: Promises, Issues, and Implications

Rong Fan, University of Washington, Seattle, WA, United States, Xuegang (Jeff) Ban

Big data and related data analytics methods have received much attention recently in transportation for various planning and operational applications. This talk summarizes the promises of big data and illustrates the issues of some commonly used big data sources in transportation. We then briefly discuss the implications of such issues and suggest a pathway that may help address those issues.

## ■ MD30

North Bldg 221C

### Facility Layout

Sponsored: TSL/Facility Logistics

Sponsored Session

Chair: Churlzu Lim, UNC-Charlotte, Systems Engineering & Engineering Management, 9201 University City Boulevard, Charlotte, NC, 28223, United States

## 1 - An Evaluation Method for Layout Design of a Spacecraft Using Canonical Correlation, Data Envelopment Analysis, and Choquet Integral

Claudia Ramirez, Doctoral Student, University of North Carolina-Charlotte, 9201 University City Blvd, Charlotte, NC, 28223, United States, Simon Hsiang, Churlzu Lim

The ideal arrangement of task spaces in a spacecraft reflects a minimal overall volume while maximizing the crewmembers' health, performance, and safety for the duration of a mission to Mars. Their "happiness" is evaluated by considering design factors that rank and score different layout designs based on the factors' priority order designated by the user. The evaluation is achieved through the relationship between the spacecraft's physical characteristics and their psychophysical attributes by using Canonical Correlation Analysis, Data Envelopment Analysis, and Choquet Integral.

## 2 - Dominance Results for the M Finite-size Facility Placement Problem

Rakesh Nagi, University of Illinois at Urbana-Champaign, Department of Industrial & Enterprise Systems, 117 Transportation Building, MC-238, Urbana, IL, 61801, United States, Ketan Date

We study the M Finite-size Facility Placement Problem: Optimally placing M new finite size rectangular facilities (NFs) in a layout with N existing rectangular

facilities (EFs). Pairs of facilities interact through Input/output points located on the facility boundary. We propose lower bounds and dominance in an implicit enumeration scheme that significantly reduces the number of candidate solutions, making this a viable solution approach in practice.

## 3 - Effect of Dynamic Demand Uncertainty on Facility Layout Design: Revisiting Integrated Facility Layouts

Melih Celik, Middle East Technical University, ODTU Endustri Muh. Bolumu, Universiteler Mh. Dumlupinar Bl. No: 1, Ankara, 06800, Turkey, Beg n Efeoglu, Haldun S ral

We consider the integrated facility layout problem (IFLP), where the aim is to determine the material or product flows among (duplicates or copies of) work centers and machines, in conjunction with their locations within the facility. In many manufacturing environments, the amount of demand may not be known in advance. For this end, we consider the stochastic IFLP in a dynamic environment where the jobs have different demand distributions in each period. We propose a dynamic programming approach based on the enumeration of possible machine assignments with given machine types, machine copies, and locations in each period. We show the effectiveness of our approach using instances from the literature.

## 4 - Overlap Cuboid Packing Optimization for Spacecraft Layout Design and Computational Enhancements

Churlzu Lim, University of North Carolina-Charlotte, Systems Engineering & Engineering Management, 9201 University City Boulevard, Charlotte, NC, 28223, United States, Richard Alaimo, Claudia Ramirez, Simon M. Hsiang

Consider a variant of the packing problem, called overlap cuboid packing problem, which allows for cuboid items to share space in order to further minimize the dimensions of the container. The objective of this study is to investigate a mixed-integer linear program that effectively provides a packing solution in the context of designing the layout for a spacecraft module. This talk will briefly review the bi-objective function that enforces specific adjacency requirements between gradient cuboids, and discuss about computational enhancements that display promising results in a numerical study.

## ■ MD31

North Bldg 222A

### Logistics, Supply Chain, and Multi-modal Transportation

Sponsored: TSL/Intelligent Transportation Systems (ITS)

Sponsored Session

Chair: Nasibeh Zanjirani Farahani, University of Missouri, E3437 Thomas and Nell Lafferre Hall, Columbia, MO, 65211, United States

## 1 - A Sim-heuristic Approach for Near Real-time Optimization of Single-track Railway Scheduling

Qi Tian, Dalian University of Technology, 2 Linggong Road, Ganjingzi District, Dalian, 116024, China, Rutgers, The State University of New Jersey, 96 Frelinghuysen Road, Piscataway, NJ, 08854, United States, Weihong Guo, Wenyan Wang, Zijian Guo

The wide applications of real-time sensing devices and big data methods are providing unprecedented opportunities for developing new solutions for single-track railway scheduling. Considering near real-time information such as unexpected delays caused by inclement weather or train breakdowns, this research develops a sim-heuristic solution algorithm to minimize the total weighted delay time. The proposed method provides near real-time optimization for single-track railway scheduling. The effectiveness of the proposed algorithm is demonstrated in both simulation and a real-world case study.

## 2 - A Scalable Non-myopic Atomic Game for Smart Parking Mechanism

Hamid R. Sayarshad, Cornell University, Ithaca, NY, 14850, United States, Shahram Sattar, H. Oliver Gao

We propose a new smart parking mechanism which seeks to reduce cruising for parking at multiple parking facilities in a crowded area. A non-myopic atomic game is formulated to search the equilibrium solution through allocating travelers to candidate parking facilities which considers travel time difference for the vehicles, walking time, dynamic pricing, cruising time and parking facilities' occupancy. This study integrates a social efficiency price which accounts customer waiting time for parking searching. We involve the network travel time variation into our dynamic policy and make the game model reflect reality better by the competition of vehicles in both road resources and parking spaces.

### 3 - Modeling a Battery Swapping Station for Electric Vehicles with Time-varying Demand

Kyle Hovey, North Carolina State University, Raleigh, NC,  
United States, Yunan Liu, Xiang Li

We model a battery swapping station (BSS) for electric vehicles that has a fixed supply of available battery charging slots. When customers arrive, the BSS will replace their drained batteries with those supply batteries having the highest charge that also meet an acceptable quality level (e.g., charge greater than 80% of capacity). Our model captures three realistic features of this process: i) time-varying arrivals, ii) non-linear battery charging, and iii) random residual charges. We take a queueing theory approach by keeping track of the real time ages of the batteries that are being charged. We give asymptotic performance analysis as the scale of the system increases.

### 4 - Relationship Between Uncertainties in Supply Chain and Its Risk Perception

Yuji Sato, Professor, Chukyo University, 101 Yagotohonmach,  
Showa, Nagoya, Aichi, 466-8666, Japan

This paper clarifies the relationship between uncertainties in supply chain and its risk perception. Rapid spread of globalization pushes firms to face the higher level of uncertainty, where they must formulate necessary and sufficient strategy for supply chain management. Such a strategy, however, involves a broad range of factors, including some that are subjective. This paper addresses this issue by refining existing structural model of supply disruption. A case study was conducted that demonstrates the applicability of the approach based on the proposed structural model to the real markets in both developed and developing countries.

### 5 - The Shortest Path Approaches with Time Window in Multi-graph Networks

Nasibeh Zanjirani Farahani, PhD Student, University of Missouri,  
E3443 Thomas and Nell Lafferre Hall, Columbia, MO, 65211,  
United States, Moein Enayati, James S. Noble,  
Ronald G. McGarvey

One of the common problems of Service Network Design is finding the shortest path. Networks as the infrastructure of the logistics are the graphs which are used to show the communications of different nodes by connection edges. Those types of networks that consider multiple edges in between two nodes are multigraphs and shortest path problems are rarely discussed on them. In this research different methods of solving shortest path problems for multigraph networks with time window are explained and new approaches to solving such problems are classified and explained. In the end, a new mathematical model and a metaheuristics algorithm to find the best path in such networks are proposed.

## ■ MD32

North Bldg 222B

### Research with Autonomous Vehicles and Platooning

Sponsored: TSL/Freight Transportation & Logistics

Sponsored Session

Chair: Ann Melissa Campbell, University of Iowa, Iowa City, IA, 52242-1994, United States

#### 1 - Dynamic Operation of Autonomous Vehicle Fleets for Urban Mobility Applications

Hani S. Mahmassani, Northwestern University, Transportation  
Center, 600 Foster Avenue, Evanston, IL, 60208-4055,  
United States, Michael Hyland

We present dynamic fleet assignment strategies for autonomous vehicle fleet operations under different business models for urban goods delivery. Recent results from shared passenger mobility applications are also discussed.

#### 2 - Dynamic Synchronization of Truck Platoons

Anirudh Kishore Bhoopalam, Erasmus University, Rotterdam,  
Netherlands, Niels Agatz, Rob A. Zuidwijk

Automated vehicle technology enables the formation of platoons in which virtually linked trucks drive closely behind one another. Platooning helps to reduce fuel consumption and emissions. In this study, we look at the dynamic planning of platoons of two trucks. To determine the platoons and the associated synchronized truck routes, we present an exact algorithm and several quick heuristics. We perform numerical experiments on different instances to study the impact of the maximum detour length and the waiting time on the total system-wide travel costs.

#### 3 - Use of Autonomous Robots for Single Package Delivery

Iurii Bakach, University of Iowa, Iowa City, IA, 52240,  
United States, Ann Melissa Campbell, Jan Ehmke

Autonomous robots can help making last-mile deliveries more efficient and customer friendly. We examine the use of robots to deliver individual packages in urban last-mile delivery. We will look at the number of robots required and time of completion as compared with traditional truck delivery models. We will examine different assumptions on the speed of travel, geography, and working hours to understand where autonomous robots are particularly valuable.

### 4 - The Impact of Parking on the Use of Autonomous Vehicles in Urban Delivery

Sara Reed, University of Iowa, Ann Melissa Campbell,  
Barrett Thomas

In the dense road network of urban areas, the time spent to find parking can impact the overall time of parcel delivery. With the use of autonomous vehicles, this time can be minimized allowing the vehicle to be in continuous travel while being used for the loading of parcels at determined locations. With capacity constraints on a delivery person between loading times, we look to analyze the relationship between these constraints and estimated time of parking. This work aims to examine the competitiveness of using autonomous vehicles for delivery in urban areas.

### 5 - Autonomous Truckload Delivery

Kamal Lamsal, Barrett Thomas, Ann Melissa Campbell

The impact of autonomous vehicles will be huge. If the vehicle no longer requires a driver, the drive time across country can be reduced. One conservative estimate is that all driving across interstate highways is done with trucks on autonomous settings and handled by a regular driver from the exit of the highway to the final destination. We study the impact of autonomous drivers on truckload shipping. We assume that if a driver is used to make the delivery, the FMCSA regulations on drivers applies. If an autonomous vehicle is used, the FMCSA regulations do not apply on interstate portion. We experiment with different distributions of deliveries to understand the impact of delivery location on final costs.

## ■ MD33

North Bldg 222C

### Joint Session ORAM/QSR/Practice Curated: Data Analytics Methods for Smart Manufacturing Systems Monitoring and Control

Emerging Topic: OR and Advanced Manufacturing

Emerging Topic Session

Chair: Mohammed Shafae, University of Arizona, Tucson, AZ, 85743, United States

Co-Chair: Dazhong Wu, University of Central Florida, FL, United States

#### 1 - A Feature-Based Data-Level Fusion Model for Degradation Modeling and Prognostics

Yupeng Wei, Pennsylvania State University, PA, United States,  
Dazhong Wu, Janis Terpenny

The rapid development of sensor technologies has enabled multiple in-situ sensors to monitor the degradation status of operation units. To achieve an accurate prediction of remaining useful life (RUL), multiple sensor signals should be fused. This work presents a new data-level fusion methodology for degradation signals based on statistical features, which is designed to provide much more accurate features to better support the prediction of RUL. In addition, 4 machine learning algorithms are facilitated to predict the RUL based on features extracted from the fused signal. Our methodology was evaluated through a degradation dataset of an aircraft gas turbine engine that was generated by C-MAPSS.

#### 2 - Parallel Computing and Network Analytics for the Monitoring of Industrial Internet-of-Things (IIoT) Machines

Chen Kan, TX, United States, Hui Yang, Soundar Kumara

This paper presents a new method for IIoT machine condition monitoring. First, dissimilarities among machine signatures were characterized. Then, we proposed a stochastic learning algorithm to construct a large-scale dynamic network of IIoT machines. When machine condition varies, the network structure is changed accordingly. A parallel computing scheme is further developed to significantly improve the computational efficiency. Results show the developed algorithm effectively and efficiently captures cycle-to-cycle dynamics of a machine and machine-to-machine variations in large-scale IIoT.

#### 3 - Cloud-Based Parallel Machine Learning for Tool Wear Prediction

Dazhong Wu, University of Central Florida, FL, United States

Cloud computing and machine learning have the potential to advance smart manufacturing. One of the limitations of current machine learning methods is that large volumes of training data are required to train predictive models. Consequently, computational efficiency remains a primary challenge. In this presentation, we will introduce a parallel random forests algorithm. This algorithm is implemented on the cloud with varying combinations of processors and memories. This algorithm is demonstrated using condition monitoring data collected from milling experiments.

#### 4 - Optimum Placement of Actuators for Large Space Structure Shape Control

Juan Du, Peking University, College of Engineering, 5 Yiheyuan Road, Beijing, 100871, China, Xiaowei Yue, Jianjun Shi

Shape control of large space structure is critical for the usage functionality. To realize large space structure shape adjustment, actuators are essential tools. Given the fixed number of actuators, different actuator placements influence the shape control capability. Optimization of actuators' placements is very important but challenging. This presentation proposes an automatic actuator placement approach for efficient large space structure shape control by developing a sparse learning model and corresponding estimation algorithm. The case study shows that our proposed method achieves good performance for shape adjustments of large space structure.

### ■ MD34

North Bldg 223

#### 4:30 - 5:15 AMPL/ 5:15-6:00 Didi Chuxing

Vendor Workshop Session

##### 1 - Model-Based Optimization + Application Programming = Streamlined Deployment in AMPL

Robert Fourer, AMPL Optimization Inc., 2521 Asbury Ave, Evanston, IL, 60201, United States, Filipe Brandão

AMPL offers the advantages of modeling in a specialized optimization environment combined with the power of application development via general-purpose programming. Optimization problems are formulated concisely and naturally in AMPL's modeling language, promoting rapid development, reliable maintenance, and evaluation of multiple solvers and data sources. APIs for popular full-featured programming languages facilitate embedding of AMPL models and scripts into complex applications, with access to data management and interface development libraries. We illustrate using AMPL's APIs for Python and R, and conclude with a preview of features for invoking Python within AMPL scripts.

##### 2 - Ride-sharing Services Research at Didi Chuxing

Didi Chuxing, Didi Chuxing, Beijing, China

Didi Chuxing is the world's leading mobile transportation platform. The company offers a full range of mobile tech-based mobility options for nearly 400 million users. As many as 20 million rides were completed on DiDi's platform on a daily basis, making DiDi the world's second largest online transaction platform. DiDi acquired Uber China in August 2016. DiDi is committed to working with communities and partners to solve the world's transportation, environmental and employment challenges using big data-driven deep-learning algorithms that optimize resource allocation. In 2016, DiDi was named one of the World's 50 Smartest Companies by MIT Technology Review.

### ■ MD35

North Bldg 224A

#### AAS Special Invited Speaker Presentation

Sponsored: Aviation Applications

Sponsored Session

Chair: Heng Chen, University of Nebraska-Lincoln, Lincoln, NE, 68588, United States

Chair: Vikrant Vaze, Dartmouth College, 14 Engineering Drive, Murdough Center, Hanover, NH, 03755, United States

##### 1 - The Dawn of Urban Aerial Ridesharing

Jon Petersen, Uber, San Francisco, CA, United States

With 2/3 of the world's population expected to live in cities within 25 years there is an upper bound to what can be done to improve urban mobility on the ground. Technological advancements from vehicles, batteries, airspace, infrastructure, and multimodality are converging to generate a new mode of urban transportation that utilize the third dimension. This talk will introduce the Uber Elevate ecosystem and specifically focus how optimization and machine learning are being used to model demand, construct networks within cities, define vehicle and infrastructure requirements, and build out and scale urban aerial ridesharing beginning in 2023.

### ■ MD36

North Bldg 224B

#### Topics in Healthcare Provider Productivity & Satisfaction

Sponsored: Manufacturing & Service Oper Mgmt/Healthcare Operations

Sponsored Session

Chair: Robert Batt, Wisconsin School of Business, UW-Madison, Madison, WI, 53706, United States

##### 1 - The Impact of Shift Changes on Medication Ordering and Delivery in the Intensive Care Unit

Lesley Meng, The Wharton School, University of Pennsylvania, 3730 Walnut Street, Suite 500 JMHH, Philadelphia, PA, 19104, United States, Ann M. Huffenberger, Krzysztof Laudanski, Christian Terwiesch

Patients spending time in the intensive care unit (ICU) of a hospital are often there to receive stabilizing, life-saving care. Providers working in this environment must pay careful attention to medication delivery so that these patients may recover as quickly as possible without complications. We utilize a comprehensive dataset consisting of all ICU patient visits across 3 academic teaching hospitals over 5 years to study the accuracy of medication orders and the timing of medications delivered.

##### 2 - Mixing It Up: Operational Impact of Hospitalist Workload

Masoud Kamalahmadi, Indiana University, 1309 E. 10th Street Room HH 4100, Bloomington, IN, 47405, United States, Alex Mills, Jonathan Helm, Kurt M. Bretthauer

Hospitalists are physicians that specialize in caring for hospital inpatients, replacing a primary care physician who may only make rounds once per day and thereby reducing delays. Given a limited number of hospitalists in a hospital, we seek to determine their optimal service mix (workload and patient types).

##### 3 - Customized Office Revisit Intervals and Evisits in Primary Care

Hessam Bavafa, Wisconsin School of Business, 4284C Grainger Hall, 975 University Avenue, Madison, WI, 53706, United States, Sergei Savin, Christian Terwiesch

The demand for physician services in primary care is shaped by the number of patients associated with each physician and the frequency of scheduled office visits. While a physician can typically set the size of her patient panel without regard for individual patient preferences, office revisit intervals are determined jointly by the physician and her patients. In our model, a physician can manage the demand for her services using two "customization approaches: (1) adjusting the office revisit intervals based on patient health status, and (2) diverting some of the patient demand away from the office visits and into "e-visits.

##### 4 - Payment Mechanisms, Incentives for Adoption and Value of Health-information Exchanges (HIEs)

Mehmet Ayvaci, University of Texas-Dallas, Richardson, TX, United States, Huseyin Cavusoglu, YeongIn Kim, Srinivasan Raghunathan

Diffusion of health information outside the boundaries of an organization through health-information exchanges (HIEs) is a critical step in achieving socially desirable care outcomes. In this paper, we study the relationships among a payment model, providers' incentives to adopt HIEs, and the value of HIEs using a game-theoretical model. We demonstrate that assessing the value of HIEs in isolation from the underlying payment mechanism and patient switching behavior may result in under- or overestimation of the HIE value. Therefore, as payment models evolve over time, there is a real need to reevaluate the value of HIE adoption and the government policies that induce providers to adopt HIE.



## ■ MD37

North Bldg 225A

### Markov Lecture

Sponsored: Applied Probability

Sponsored Session

Chair: Jose Blanchet, Columbia University, New York, NY, 10027, United States

Co-Chair: Rami Atar, Technion, Technion, Haifa, 32000, Israel

Co-Chair: Amber L. Puha, California State University-San Marcos, San Marcos, CA, 92096-0001, United States

#### 1 - Adaptive Estimation using Regularized Empirical Risk

Sara van de Geer, PhD in Mathematics in 1987 at Leiden University, ETH Zurich, Zurich, 8092, Switzerland

We examine a general class of algorithms based on minimizing an empirical risk function. Examples of empirical risk functions are the least squares risk, and more generally a minus log-likelihood. We consider complex models, for example models with a large number of parameters. Adding a penalty to the empirical risk will help to avoid overfitting. Our focus will be on norm-penalized estimators, where the norm is inducing sparsity. Aim is to show why such penalties lead to favourable theoretical properties namely adaptivity to both complexity and curvature. Moreover, the results do not always require the estimator to be a global minimizer.

#### 2 - Discussant

Alexandre Belloni, Duke University, Fuqua School of Business, 100 Fuqua Drive, Durham, NC, 27708, United States

## ■ MD38

North Bldg 225B

### Innovative Traffic Control and Operations

Sponsored: TSL/Intelligent Transportation Systems (ITS)

Sponsored Session

Chair: Larry Head, University of Arizona, Tucson, AZ, 75719, United States

Co-Chair: Qing He, University at Buffalo, SUNY, Buffalo, NY, 14260, United States

#### 1 - Understanding the Problem: Traffic Safety Analysis

Brendan Russo, Assistant Professor, Northern Arizona University, P.O. Box 15600, Flagstaff, AZ, 86011, United States

Traffic crashes cost society billions of dollars each year as a result of property damage, injuries, fatalities, and non-recurring delay. This analysis explores factors affecting the frequency and severity of crashes along the Arizona portion of the I-10 corridor, with a particular focus on freight-related crashes. The safety performance along the I-10 is analyzed through the development of crash frequency and severity prediction models using integrated crash, roadway, traffic, and environmental data. The results showed that several roadway-, crash-, vehicle-, and person-specific variables were associated with the frequency and/or severity of crashes along the study corridor.

#### 2 - Machine Learning Investigation using Integrated Data for Identification of Critical Factors for Safety and Mobility

Zuoyu Miao, University of Arizona, Tucson, AZ, United States

Potential safety and mobility concerns are rising due to the facts that huge losses could occur by the risks of accidents and travel time degradation. To identify critical factors leading to potential losses, multiple data sources are investigated, including history crash reports, travel time records, weather information, etc. Several statistical machine learning methods are combined for analyzing above data and identifying critical factors. Based on identified critical factors and their related impacts, several different countermeasures are discussed for avoiding severe accident injuries and decreasing the accident frequency.

#### 3 - Quantifying Freight Performance Measures using Multisource Traffic Data

Abolfazl Karimpour, Graduate Research Assistant, The University of Arizona, Tucson, AZ, United States, Yao-Jan Wu

With the emerging development of Intelligent Transportation System (ITS) technologies, surface-transportation data can now be collected by a wide variety of ITS traffic detectors, including Bluetooth detectors, automatic vehicle location (AVL) devices, inductive loop detectors, and radar-based detectors. It has been challenging to take full advantage of the ITS data from multiple sources by enabling them to exchange information with each other to compensate for their various disadvantages. This presentation will be focused on freight performance measurement using multi-source traffic data collected on the Arizona freeway network.

#### 4 - Optimizing Traffic Signals Using Multi-source Data: From a Practical Perspective

Yao-Jan Wu, Assistant Professor, University of Arizona, 1209 E. 2nd St. Room 324F, Civil Engineering, Tucson, AZ, 85721, United States

Cities have invested a great deal amount of funding in intelligent transportation systems, especially traffic sensor technologies, to better manage traffic and reduce congestion. However, not all cities/agencies have fully utilized the capacities of the advanced technologies. This presentation aims at providing data-driven solutions to enhancing traffic data usability for optimizing traffic signal timing using multiple sources of data. Different from traditional operation research, this presentation focuses more on the practical side of traffic signal optimization and take other key factors, such as safety and operability into account during the signal re-timing process.

## ■ MD39

North Bldg 226A

### Supply Chain Risk Management

Sponsored: Manufacturing & Service Oper Mgmt

Sponsored Session

Chair: Florian Lucker, Cass Business School, London, EC1Y 8TZ, United Kingdom

#### 1 - Recall Analytics and Supply Chain Risk

Ahmet Colak, Clemson University, Greenville, SC, 29601, United States, Robert Louis Bray

Product safety is one of the most critical drivers of brand equity and reputation in consumer goods industries. I will focus on how automakers trade off between defect liabilities and product recalls, using a sample of 1M consumer defect reports and 15K component recalls. I will also talk about how the federal government enforces its mandated-recall programs, studying the government-initiated recalls for a period of 20 years. I will then elaborate on the supply chain drivers of quality defects from a sample of 26K auto suppliers. And last, I will discuss about data analytics tools to improve failure and recall prediction accuracy dynamically, mining detailed defect report statements.

#### 2 - Inventory Dispersion in a Sequential Inventory System with Demand Forecast Evolution

Isik Bicer, Swiss Federal Institute of Technology in Lausanne (EPFL), Chemin de Veilloud 11, Ecublens, 1024, Switzerland, Florian Lucker

Inventory dispersion along a supply chain occurs as raw materials are processed and allocated to the production of different end-products, and also when the end-products are sent to different locations to be sold to the customers. We develop a dynamic optimization model to find the optimal order quantities in a multi-echelon setting such that inventory dispersion may occur in different echelons and the demand forecasts of the end products evolve according to a multiplicative martingale model. We show that postponing high-cost activities leads to higher profits than postponing the point of differentiation.

#### 3 - Examining Resiliency in Pharmaceutical Drug Supply Chain Considering Human Behaviors Component

Rozhin Doroudi, Northeastern University, Boston, MA, 02116, United States, Ozlem Ergun

The growing epidemic of drug shortages in the United States demonstrates the lack of resiliency within drug delivery supply chain. A key, and often understudied, element in resiliency of supply chains is the role of human behavior. Human decision makers should anticipate and react to the contingencies and disruptions that arise. We propose an integrated simulation framework which allows for instantiating, testing, and improving supply chain resiliency while accounting for human behavior component. We demonstrate the applicability of our method through several experiments.

#### 4 - Scheduling Optimization in Continuous Steel Casting and Rolling Operations

Joshua Betz, Colorado School of Mines, CO, 80401, United States

In continuous steel casting operations, molten steel is batched into heats inside a ladle that is cast into slabs, which are then rolled into coils. We present a mixed integer program to produce a daily casting schedule that is solved using state-of-the-art software. This model minimizes penalties incurred by violating plant best practices while strictly adhering to safety and logical constraints to manage risk for manufacturing incidents that can occur in the rolling mill. A heuristic produces an initial feasible solution to expedite the generation of near-optimal schedules.

## 5 - Disruption Risk Management in Serial Multi-echelon Supply Chains

Florian Lucker, Cass Business School, 106 Bunhill Row, London, EC1Y 8TZ, United Kingdom, Sunil Chopra

This talk deals with managing supply chain disruption risk in a multi-echelon serial supply chain using risk mitigation inventory and reserve capacity. We show that it is typically optimal to hold more risk mitigation inventory downstream than upstream. At the same time, it is often optimal to hold additionally more reserve capacity downstream than upstream. These results hold under the assumption that inventory and reserve capacity holding costs are larger downstream than upstream.

## ■ MD40

North Bldg 226B

### Utility Theory Developments

Sponsored: Decision Analysis

Sponsored Session

Chair: Ying He

#### 1 - Shapley Values, Interactions and Supermodularity

Emanuele Borgonovo, Bocconi University, Via Sarfatti 25, Milano, 20136, Italy, Giovanni Rabitti

In this work, we present a miscellanea of results concerning the study of interactions in decision analysis modelling. We show the link between interactions and supermodularity. We contrast these findings to the study of interactions as determined by the Shapley-Owen value.

#### 2 - Simulated Decision Processes

Fabio Maccheroni, Università Bocconi, Via Sappfath, 25, Milan, Italy, Carlo Baldassi, Simone Cerreia-Vioglio, Massimo Marinacci

A successful model to describe two-alternative speeded decisions between consumption goods is the Drift Diffusion Model (DDM) of Ratcliff (1978). In this paper, we provide an axiomatic foundation for the DDM. Our axioms present a test for model misspecification and connect the externally observable properties of choice induced by the DDM with its mechanistic account of the choice process. Moreover, by combining binary DDM comparison with Markovian exploration, we extend the DDM to multi-alternative choice. The resulting “Metropolis-DDM algorithm” is consistent with the eye-tracking findings of Russo and Rosen (1975), converges to the multinomial logit, and is robust to discretization.

#### 3 - Revisiting Ellsberg and Machina's Paradoxes: A Two Stage Evaluation Model Under Ambiguity

Ying He, University of Southern Denmark, Campusvej 55, Odense, M, 5230, Denmark

We revisit the Ellsberg paradox by showing that the preference does satisfy the independence axiom under a weak assumption. Such an observation motivates us to develop a two-stage model for decision making under ambiguity. This two-stage model can not only accommodate preferences in different versions of Ellsberg's paradoxes but also the preferences in paradoxes recently proposed in Machina (2009, 2014) that challenge the validity of many existing models for decision making under ambiguity. Finally, we propose some conjectured examples to illustrate how our model becomes more flexible compared with some existing models in the literature without sacrificing the parsimony of the model.

## ■ MD41

North Bldg 226C

### Decision Analysis Society Awards

Sponsored: Decision Analysis

Sponsored Session

Chair: Jason Merrick

#### 1 - 2018 Decision Analysis Practice Award Competition

Saurabh Bansal, Penn State University, 405 Business Building, State College, PA, 16801, United States

This session will showcase the finalists for the 2018 Decision Analysis Practice Award Competition. The specific talks in the session will be listed as the finalists are identified and consent to present in the session.

## ■ MD42

North Bldg 221C

### Infrastructure Systems Towards a Smart City

Emerging Topic: Smart Cities

Emerging Topic Session

Chair: Hiba Baroud, Vanderbilt University, Nashville, TN, 37235, United States

#### 1 - Analyzing Socially Considerate Multi-Modal Routing Algorithms

Chinmaya Samal, Vanderbilt University, Nashville, TN, United States, Abhishek Dubey

Ride-sharing platforms such as Uber and Lyft are becoming a more commonplace, particularly in urban environments. While such services may be deemed more convenient than riding public transit due to their on-demand nature, reports show that they do not necessarily decrease the congestion in major cities. In this presentation, we will describe socially considerate multi-modal routing algorithms that are proactive and consider, via predictions, the shared effect of riders on the overall efficacy of mobility services. Our results indicate that even at a low penetration (social ratio), we are able to achieve an improvement in system-level performance.

#### 2 - Modernization of Buildings: The Interplay of Buildings and Smart Cities' Emerging Systems

Atefe Makhmalbaf, University of Texas-Arlington, Arlington, TX, United States

Buildings are an integral part of the built environment. Americans spend about 90% of their time indoors. Hence, building design and operation have direct impact on occupant's health and productivity. Moreover, buildings consume about 40% of energy and 72% of electricity and contribute to 34% of greenhouse gas emissions. Successful deployment of smart cities necessitates design of smart buildings. This presentation will discuss the evolving roles of buildings and the importance of decision support systems during all phases of a building life-cycle from design, to construction and operation to satisfy the broader objectives of smart cities including those of sustainability and resiliency.

#### 3 - Water Infrastructure Resilience: Measurement and Optimization

Mohsen Shahandashti, Assistant Professor, University of Texas at Arlington, Arlington, TX, United States

A variety of metrics could be used to measure the resilience of water distribution networks subjected to natural hazards, such as earthquakes. Selection of resilience metrics has a significant impact on formulating optimized rehabilitation policies. This significant impact is highlighted by comparing various optimized policies for proactive seismic rehabilitation of a water pipe network based on different resilience metrics. These results highlight the importance of aligning resilience measurement with the experience and expectations of water utilities to formulate effective proactive rehabilitation policies.

## ■ MD43

North Bldg 227B

### Sandia Session

Emerging Topic: Energy and Climate

Emerging Topic Session

Chair: Peter Kobos, Sandia National Laboratories, NM, United States

Co-Chair: John Eddy, Sandia National Labs, Albuquerque, NM, 87185-1011, United States

#### 1 - The Microgrid Design Toolkit

John Eddy, Sandia National Labs, P.O. Box 5800, Albuquerque, NM, 87185-1011, United States

The MDT is a visual design and trade-space optimization capability for microgrids. It uses a multi-objective optimization algorithm that executes a discrete event Monte-Carlo simulation to characterize performance and reliability of candidate microgrid designs. The output is a Pareto frontier of efficient alternative microgrid designs and visualizations to help a designer understand the trade-offs. This presentation will describe the technology underlying the MDT and discuss some recent analyses conducted.

## 2 - Offline Framework to Optimize Current Energy Converter Simulation with Multiple Correlated Functional Response

Sterling Stewart Olson, Sandia National Labs, Albuquerque, NM, 87185, United States, Chris Chartrand, Jesse Roberts, Humberto Silva, Cheping 'Jack' Su

Current energy converters are an important component of sustainable energy. However experimental measurements are prohibitively expensive making modeling a critical component to increasing the technology readiness level of devices. This research sought to optimize a Gaussian process regression meta-model relating four turbulence parameter inputs to two outputs (velocity and turbulent intensity) related by partial differential equations as a function of distance for a long wall clock simulation. The meta-model optimized parameters showed acceptable results for a ten-fold decrease in total simulation time and provides many opportunities for future research.

## 3 - Rolling Horizon Optimization for a H2Electrolyzer Station Used to Service H2 Vehicles

Ross Guttromson, PhD, Sandia National Labs, Albuquerque, NM, 87185, United States

The integration of hydrogen vehicles into the US transportation system relies upon coordinated access to various energy supply systems. The diversity of these energy supplies helps to manage cost and resilience, but will also add complexity with regards to economic and other operating decisions. A multi-period, rolling-horizon optimization was developed to provide reliable and sound economic, real-time decisions for a hydrogen electrolyzer system used to fulfil potential H2 vehicle demand. The optimization considers decisions associated with the purchase of wind and solar renewable energy, storage of H2, the purchase of electricity on a day-ahead basis, the sale of excess electricity on a real-time market, fulfillment of station service electrical demand, and the sale of a zero-net-energy regulation product, similar to the PJM RegD market. This model was also used to economically size the infrastructure based on demand and price forecasts.

## 4 - Design of Community-Focused Resilience Metrics for Effective Infrastructure Investment

Robert Fredric Jeffers, PhD, Sandia National Labs, Albuquerque, NM, 87185, United States

Abstract not Available

## 5 - Power System Resiliency Reliability Cooptimization

Bryan Arguello, R&D Computer Science, Sandia National Labs, 1515 Eubank Blvd. SE, NM, Albuquerque, NM, 87123, United States, Brian Pierre, Shabbir Ahmed, Emma Johnson

The purpose of our work is to co-optimize power system reliability and resiliency investment decisions. Our working definition of resiliency is resistance to load shed during low-probability, high-impact events. Similarly, we define reliability as resistance to load shed during high-probability, low-impact events. We have developed both a distribution-level reliability investment model driven by historical outage data, and a transmission-level stochastic resiliency investment model driven by extreme weather event scenarios. Through our co-optimization technique, we explore the tradeoff between transmission resiliency and distribution reliability when the models share a budget.

## ■ MD44

North Bldg 227C

## Joint Session ENRE/Practice Curated: Optimization and Machine Learning for Electric Power Systems

Sponsored: Energy, Natural Res & the Environment/Electricity  
Sponsored Session

Chair: Yu Zhang, PhD, UC Santa Cruz, 1156 High St SOE2, Santa Cruz, CA, 95064, United States

## 1 - Application of Machine Learning to Distribution Synchrophasors

Alireza Shahsavari, University of California, Riverside, Riverside, CA, United States, Hamed Mohsenian-Rad

The recent development of distribution-level phasor measurement units, a.k.a. micro-PMUs, has been an important step towards achieving situational awareness in power distribution networks. A typical micro-PMU is connected to single- or three-phase distribution circuits to measure GPS time-referenced magnitudes and phase angles of voltage and current phasors at 120 readings per second. The challenge in using micro-PMUs is to transform the large amount of data that is it generates to actionable information and match the said information to use cases with practical value to distribution system operators. In this talk, we adopt a big-data approach to address this open problem. We introduce a novel data-driven event detection technique to pick out valuable portion of data from extremely large raw micro-PMU dataset. We then develop a data-driven event classifier to effectively classify power quality events. Importantly, we use field expert knowledge and utility records to conduct an extensive data-driven event labeling. Certain aspects from event detection analysis are adopted as additional features to be fed into the classifier model.

## 2 - Joint Structure and Parameter Estimation in Power Distribution Under Limited Observability

Deepjyoti Deka, Los Alamos National Lab

Efficient operation of distribution grids in the smart-grid era is hindered by the limited presence of real-time meters. This paper studies the problems of topology and parameter estimation in the limited observability regime where measurements are restricted to only the terminal nodes of the grid and all intermediate nodes are unobserved/hidden. To this end, we propose two algorithms for exact topology (and impedances) estimation. We discuss the computational and sample complexity of our proposed algorithms and demonstrate that topology (and impedance) estimation by our algorithms are optimal with respect to number of nodal observability required.

## 3 - Stochastic Continuous Time Unit Commitment

Anna Scaglione, Arizona State University, Tempe, AZ, United States, Kari Hreinsson, Bitá Analui

Conventional power system unit commitment problems are deterministic and assume piece wise constant behavior of net-load, while in reality net-load is uncertain and inter-period generator ramps are not well defined. We will discuss a stochastic continuous time problem formulation, where we try to give a more realistic generator ramp trajectories, as well as incorporating a multi-stage stochastic decision framework, where dispatch decisions are revised over the modeling horizon.

## 4 - Wind Power Forecasting via Deep Neural Networks

Yu Zhang, University of California, Santa Cruz, Jiao Hao Miao

Accurate forecasting of renewable generation is a challenging task due to its inherent intermittency and volatility. In this context, this talk deals with a new machine learning approach for predicting wind power generation with various meteorological factors including wind speed, direction, humidity, etc. We first utilize data visualization techniques for the feature selection, and then develop a deep neural network to predict the wind power outputs. Numerical results show that our proposed approach outperforms existing methods including persistence, support vector regression and ARMA.

## ■ MD45

North Bldg 228A

## Equilibria in Low-Carbon Electricity Markets

Sponsored: Energy, Natural Res & the Environment/Electricity  
Sponsored Session

Chair: Rodrigo Moreno, University of Chile, Santiago, Chile

Co-Chair: Francisco Munoz

## 1 - Investigating the Role and Value of Flexible Technologies in Low Carbon Deregulated Electricity Markets

Dimitrios Papadaskalopoulos, Imperial College-London, London, United Kingdom

The challenges associated with the decarbonization and the deregulation of electricity markets have attracted significant interest around the role and value of new flexible technologies such as flexible demand and energy storage. The author will present a new multi-period equilibrium programming model of the electricity market, capable of capturing for the first time both the strategic behavior of independent market players and the complex time-coupling characteristics of new flexible technologies. Results from case studies on a UK-based test market will demonstrate the impacts of these technologies on the business case of different market players and the overall efficiency of the market.

## 2 - Equilibrium Analysis of a Tax on Carbon Emissions with Pass-through Restrictions and Side-payment Rules

Francisco David Munoz, Universidad Adolfo Ibáñez, Santiago, Chile, Gabriel D az, Rodrigo Moreno

We develop an equilibrium model with endogenous investments in generation capacity to quantify the economic inefficiencies of an emissions policy with pass-through restrictions and side-payment rules. We provide general results that show that social costs and long-term electricity prices are always lower under a standard carbon tax than under an emissions policy with such restrictions. We explore the effects of the policy through numerical experiments and find that its effect on carbon emissions is ambiguous. Tax revenues can be much higher under such emissions policy than under a standard carbon tax, which gives the regulator weak incentives to modify the regulation.



### 3 - Impacts of Proactive Expansion Planning Under Multiple Equilibria on Generation Expansion Decisions

Enzo E. Sauma, Pontificia Universidad Catolica de Chile,  
Ave. Vicuna Mackenna 4860, Santiago, Chile, David Pozo,  
Javier Contreras

We use a proactive three-level equilibrium model for power transmission and generation expansion to study the potential impacts of proactive expansion planning on generation expansion decisions. In particular, we show that proactive transmission expansion decisions may lead to suboptimal solutions when the generation expansion equilibrium problem have multiple solutions (i.e., leading to higher total costs and lower social welfare). The resulting formulation is stated as a mathematical program subject to an equilibrium problem with equilibrium constraints (EPEC). To deal with this problem, we also propose an approach to derive tractable EPEC solutions with global optimality guaranteed.

### 4 - Market Design Considerations for Scarcity Pricing

Anthony Papavasiliou, Universite Catholique de Louvain, Center  
for Operations Research and Econometrie, Voie du Roman Pays 34,  
Louvain la Neuve, 1348, Belgium

Scarcity pricing can potentially remunerate flexibility within the context of an energy-only market design. A crucial aspect of scarcity pricing is the back-propagation of real-time scarcity signals to earlier forward markets. The successful back-propagation of scarcity signals hinges on a variety of specific short-term electricity market design choices, including (i) the trading of reserve capacity in real time, (ii) virtual trading, and (iii) the timing of the clearing of reserve capacity in day-ahead markets. In this presentation we propose a family of stochastic equilibrium models for addressing how each of these market design choices affects the back-propagation of scarcity signals.

## ■ MD46

North Bldg 228B

### Joint Session ENRE/Practice Curated: Energy Modeling: Open Source, Applications and New Developments

Sponsored: Energy, Natural Res & the Environment/Energy

Sponsored Session

Chair: Denis Lavigne, PhD, Royal Military College St-Jean, 15, rue  
Jacques-Cartier Nord, St-Jean-sur-Richelieu, QC, J3B 8R8, Canada

#### 1 - Representing the Demand Side in Energy System Optimization Models

Benjamin D. Leibowicz, Assistant Professor, University of Texas-  
Austin, ETC 5.128D, 204 E. Dean Keeton St. C2200, Austin, TX,  
78712-1591, United States

Energy system optimization models have traditionally focused on supply-side technology investment and operation decisions. They often neglect demand-side dynamics related to end-use technology choices and demand levels because they are determined by myriad actors making individual decisions. This presentation outlines methodologies for representing the demand side in energy system optimization models, with OSeMOSYS formulations of transportation and buildings as examples.

#### 2 - Storage End Effects and the Value of Stored Energy

Taco Niet, British Columbia Institute of Technology,  
3700 Willingdon Avenue, Burnaby, BC, V5G 3H2, Canada

High temporal resolution modelling of energy systems often requires modelling a number of sub-periods, with the end condition of one sub-period being used to seed the next. When storage is modeled a challenge is to keep the model from draining the stored energy at the end of each sub-period. A common approach is to model extra-long sub-periods and to discard this end effect, increasing computational complexity. We evaluate the alternative of assigning a monetary value to the stored energy at the end of each sub-period using the OSeMOSYS energy system model. We find that assigning a monetary value to storage is an effective method to reduce the impact of end effects when modelling storage.

#### 3 - Osemosys.org and the Global Climate-land-energy-water Model: An Integrated Resource Assessment Tool Supporting Sustainable Pathways for the Energy System

Mark Howells, KTH Royal Institute of Technology, Brinellvagen 68,  
Stockholm, 10044, Sweden, NA, Agnese Beltramo,  
Constantinos Taliotis

The Open Source Energy Modelling System (OSeMOSYS) was used recently to perform integrated resource assessment analysis. In these applications, the modelling framework has been enhanced to represent interlinkages in between natural resources and identify possible Climate, Land, Energy and Water strategies (CLEWs) towards more sustainable development pathways for the energy system. In this context, the Global Least-cost User-friendly CLEWs Open Source Explorative (GLUCOSE) model is presented as an example of the developed methodology. It will provide an overview of the resource constraint the environment is facing at the global level and which might affect the energy system in the long run.

### 4 - An Overview of Past, Present and Future GHG Emissions and Objectives for Canada Leading to Open-source Energy Modeling

Denis Lavigne, Professor, Royal Military College Saint-Jean, 29,  
rue Louis-Frechette, Saint-Jean-sur-Richelieu, QC, J2W 1E9,  
Canada

This talk presents an overview of past, present and future GHG emissions and objectives for Canada. The discussion also includes emissions intensities and provincial figures through the years. A parallel history of some particular bottom-up energy modeling tools is presented. It leads to the opportunity to use an open-source modeling framework such as OSeMOSYS to model cities and provinces of Canada. Examples of such existing work is presented.

#### 5 - Open Source Multi-state Continental Investment Models to Support an Analysis Ecosystem

Mark Howells, Royal Institute of Technology (KTH), Stockholm,  
Sweden, Hauke Henke, Nandi Moksnes, Constantinos Taliotis,  
Agnese Beltramo

Large multi-state electricity generation investment models have been developed. They can be absorbed into teaching programs; extended for special research applications; reduce the time needed to have a functional model and allow for the extraction of sub-models: either single or multi-state. At present such models exist for three regions of the world. These are TEMBA, SAMBA and OSEMBE for Africa, South America and EU-28 respectively. A model for North America are yet to be developed. This paper discusses pertinent aspects of these model bases and lays out challenges to be addressed.

## ■ MD47

North Bldg 229A

### Joint Session Tutorial/Practice Curated: Coalescing Data and Decision Sciences for Analytics

Emerging Topic: Practice Curated Track

Emerging Topic Session

Chair: Lewis Ntamo, Texas A&M University, 3131 TAMU,  
College Station, TX, 77843, United States

#### 1 - Coalescing Data and Decision Sciences for Analytics

Suvrajeet Sen, University of Southern California, Daniel J. Epstein  
Dept. of, Industrial and Systems Engineering, Los Angeles, CA,  
90089-0193, United States, Yunxiao Deng, Junyi Liu

The dream of analytics is to work from common data sources, so that all of its facets (descriptive, predictive, and prescriptive) are supported via a coherent data-driven vision. This vision of analytics is what we refer to as "Integrative Analytics". In this tutorial we will cover a variety of OR/MS applications that require specific statistical learning models to be integrated with optimization models. For instance, certain cross-sectional data describing dependence among random variables may lead to regression models with multivariate error terms to be integrated with Stochastic Programming (SP) models. Others may require time series models to be integrated with Stochastic Model Predictive Control (S-MPC). Still other examples lead to particle filtering models providing data for network routing. In essence this tutorial will use these illustrations to motivate a new class of models, which we refer to as Learning Enabled Optimization (LEO) models. As suggested in the title of this tutorial, the applications are derived from integrative analytics. In addition to presenting these examples, the tutorial will cover fundamental concepts for modeling, statistically approximate solution concepts, sampling-based algorithms, and finally, model assessment and selection in the context of LEO models. Given the novelty of this paradigm, we will also outline how instructors may use the material for a graduate course on integrative analytics.

## ■ MD48

North Bldg 229B

### Multi-Scale Feedbacks in Food-Energy-Water Decisions

Sponsored: Energy, Natural Res & the Environment Environment & Sustainability

Sponsored Session

Chair: Robert Barron, The University of Kansas

Co-Chair: Misty Porter, University of Kansas, Lawrence, KS, United States

#### 1 - Pareto Optimality in Group Utility Functions

Ali E. Abbas, University of Southern California, 3650 McClintock Ave, OHE 310R, Los Angeles, CA, 90089, United States, Zhengwei Sun

The Pareto optimality condition is a widely used assumption in group decision making. It requires that if each individual in the group prefers one alternative to another, then the group as a whole should prefer that alternative. This condition implies that the group utility function is an additive combination of the utility functions of the group members. We argue that Pareto optimality is a desirable property for deterministic decisions but it need not be desirable for lotteries. We present a new condition "independence of indifferent group members." We show that it is a weaker condition than Pareto optimality and derive the corresponding functional form of the group utility function.

#### 2 - Science for Creative Solutions: Obtaining Sustainable Agriculture in Arid Regions when the Well Runs Dry

Mary C. Hill, Professor, The University of Kansas, 1440 Naismith Drive, 170D Slawson, Lawrence, KS, 66045-0001, United States, Robert Barron

The proposed FEWTUREsim (Food, Energy, and Water Technology Use in Resilient Environmental and economic sustainability Simulations) provides a vision of sustainable water and energy use and economic resilience in agricultural systems. Here, we discuss the object-oriented program design and proposed tests with use cases from arid rural communities. Any analysis that ignores global effects such as energy demand and supply and resulting costs, and climate change scenarios will produce a false assessment of system risks. Integration with results from selected GCAM simulations are explored as a way to account for global scale concerns.

#### 3 - Discover Water: An Interactive Spatio-temporal Framework for Scalable Multivariate Analysis

Misty Porter, University of Kansas, Lawrence, KS, United States, Mary Hill

Combining qualitative and quantitative reasoning within a visual context supports the need for collaborative conservation to protect water resources. Previous work resulted in a visualization platform capable of clearly depicting correlations and suggesting interdependencies between time-varying, spatially-distributed quantities; it is called DiscoverWater. DiscoverWater is a time-evolving map and graphs based on time-series data. Together, these components elucidate trends so that the user can try to envision the relations between groundwater-surface water interactions, the impacts of pumping on these interactions, and the interplay of climate.

#### 4 - Evaluating Sustainability of Energy Development Using Multi Criteria Decision Analysis: A Case Study on Mexico

Rodrigo Mercado, University of Massachusetts-Amherst, Amherst, MA, United States, Erin Baker

This paper examines the use of multi criteria decision analysis (MCDA) to evaluate the sustainability of different expansions in the Mexican Electrical Grid. In particular, we will include the transmission, generation, natural gas and CO<sub>2</sub> storage networks into the evaluation of sustainability for each pathway. We use a set of social, economic and environmental criteria to evaluate the sustainability of each expansion plan up to 2050. The goal will be to use the insight of the sustainability of each expansion plan to better inform decision maker in developing energy policy.

#### 5 - Modeling the Intersections of Food Energy and Water in Climate Vulnerable Ethiopia with an Application to Small Scale Irrigation

Ying Zhang, Johns Hopkins University, Baltimore, MD, United States, Sriram Sankaranarayanan, Jess Carney, Wanshu Nie, Ben Zaitchik, Sauleh Ahmad Siddiqui

To understand the coupled FEW dynamics, we are developing a multi-player micro-economic (MME) partial-equilibrium model. The MME studies how shocks such as drought and development of resilience technologies would influence the system. The MME model is based on aggregating individual optimization problems for relevant players to capture food and energy supply chain across zones. As small-scale irrigation has been promoted as a resilience technology that could affect food security and economic well-being in Ethiopia, here, we focus on the energy usage for small-scale irrigation and the collective impact on crop production and water resources across zones in the MME model.

## ■ MD49

North Bldg 230

### Joint Session ENRE/Practice Curated: One and Two-level Equilibrium Modeling with Applications in Energy

Sponsored: Energy, Natural Res & the Environment/Energy

Sponsored Session

Chair: Steven A. Gabriel, University of Maryland, University of Maryland, College Park, MD, 20742-3021, United States

Co-Chair: Ben Hobbs

#### 1 - A Median Function Approach for Discretely Constrained Equilibrium Problems

Steven A. Gabriel, University of Maryland, Dept Civil Environ Eng, 1143 Glenn L. Martin Hall, College Park, MD, 20742-3021, United States

In this talk we present a new approach for solving discretely constrained, complementarity problems. Such problems can related to energy markets with discrete (e.g., go-no go) restrictions and also equity-enforcing restrictions. The result is a mixed integer nonlinear program based on finding the zero of a certain median function and then minimizing the norm of this function subject to integer and other constraints. The approach is presented with both theory and numerical results to proof its usefulness.

#### 2 - Equilibria in Electricity and Gas Systems under Limited Information Interchange

Antonio J. Conejo, The Ohio State University, Department of Integrated Systems Engineering, 210 Baker Systems Building, Columbus, OH, 43210, United States, Sheng Chen, Ramteen Sioshanshi

We consider the independent but interrelated operation of a gas system and a power system. The gas operator seeks maximum gas supply profit by solving a second order conic problem, while the electricity operator seeks minimum electricity supply cost by solving a linear programming problem. CCGTs link significantly the operation of both systems. We characterize the equilibria reached under different levels of communication granularity (both temporal and spatial) between the gas and electricity system operators.

#### 3 - Long-term Electricity Market Equilibria with Storage in the Presence Stochastic Renewable Infeed

Christoph Weber, PhD, University of Duisberg-Essen, Essen, Germany

Renewable energy sources (RES) in the electricity system increase the need for flexible balancing of supply-dependent infeed, storage is thereby one important option. We formulate the long-term partial equilibrium model for competitive electricity markets with conventional generation, storage and stochastic infeed represented by a discrete recombining tree. We explore the KKT conditions to derive operation principles for storage based on a time-varying position in the supply stack resulting from stochastic changes in the co-state variable. Additionally, characteristics of the long-term investment equilibrium are derived based on the zero-excess profit condition.

#### 4 - Strategic Multinational Transmission Expansion Planning using a Three-stage Equilibrium Model

Simon Risanger, MSC, Norwegian University of Science and Technology, Trondheim, Norway, Martin Kristiansen, Paolo Pisciella

Market agents often have different objectives and ignoring this can lead to inefficient markets. An example is multinational transmission expansion planning, where countries maximize their own social welfare, while system and market operators want system optimal results. To confront this challenge, we propose a three-stage equilibrium model. By exploiting relationships between binary variables from disjunctive constraints and dual variables, a mixed integer linear problem providing global optimum is formulated. The method is demonstrated on a case study of the North Sea Offshore Grid.

## ■ MD50

North Bldg 231A

### Freestyle O.R. Supreme: Frame that Problem

Sponsored: INFORMS Section on Practice (formerly CPMS)

Sponsored Session

Chair: Carrie Beam, University of Arkansas, Walnut Creek, CA, 94596, United States

#### 1 - Freestyle OR Supreme Moderator

Carrie Beam, University of Arkansas, Walnut Creek, CA, 94596, United States

Join us at our Freestyle OR Supreme competition. Our 'clients' will present their OR/Analytics problem to our teams, who will have to formulate and present their OR/Analytics solution on the fly - with no Internet. This is great experience to frame and solve a problem quickly, and a great showcase for any budding consultants (or hiring companies) out there. Winners will be selected by the client, with possible influence from audience applause.

#### Panelists

James T. Williams, FICO, 2665 Long Lake Rd, Building C, Roseville, MN, 55113, United States

Aaron Burciaga, Booz Allen Hamilton, 4305 Majestic Lane, Fairfax, VA, 22033, United States

Sanjay Saigal, Graduate School of Management, UC Davis, 327 Oakwood Place, Menlo Park, CA, 94025, United States

Kenneth J. Fordyce, Arkieva, 5460 Fairmont Drive, Wilmington, DE, 19808, United States

## ■ MD51

North Bldg 231B

### Scheduling II

Emerging Topic: Project Management and Scheduling, in Memory of Joe Leung,

Emerging Topic Session

Chair: Yumei Hou, City University of New York, College of Staten Island

#### 1 - Multitasking Scheduling Problem with Deteriorating Job and Efficiency Promotion

Yan Wang, Northwestern Polytechnical University, Xi'an, China, Junqiang Wang

In a human-related scheduling environment, operators have a need for multitasking to cope with the challenges like deterioration effect. Multitasking scheduling allows the processing of a primary job can be interrupted by waiting jobs that are available but unfinished. We consider the position-dependent deterioration of the primary job, and positive effect of the waiting jobs on efficiency promotion. This research trades off gains in multitasking against losses in deterioration effect. The related research methods and results will provide a scientific support to efficiently improve production scheduling performance, and further a new insight to better understand human-related behavior.

#### 2 - Minimizing Total Completion Time on Flow Shop with Unavailability Constraint

Hairong Zhao, Purdue University Northwest, 2200 169 Street, Hammond, IN, 46323, United States

We consider the problem of minimizing total completion time on 2 stage flow shop with the unavailability constraint on the second machine. We show that some special cases are solvable optimally in polynomial time. For the general case, the problem is extremely difficult. We develop some meta-heuristics whose performance is evaluated by experimental results.

#### 3 - Multicriteria Scheduling Subject to Limited Machine Availability

Yumei Huo, City University of New York, College of Staten Island, 2800 Victory Boulevard, 1N 215, Staten Island, NY, 10314, United States

We study the problems of multi-criteria scheduling subject to machine availability. As Panwalkar et al. points out, decision makers are often faced with the problem of satisfying several different groups of people simultaneously. On the other hand, machines may not be continuously available due to breakdown, preventive maintenance or processing unfinished jobs from a previous planning horizon. So it is natural to consider bi-criteria scheduling subject to the limited machine availability. Theoretically, the problems of multi-criteria scheduling subject to machine availability are more complicated. In this talk, we will present all the polynomial solvable problems.

#### 4 - Multi-compartment Vehicle Routing Problem for Oil Products Distribution with Transshipment

Yaxian Zhou, Dalian University of Technology, No 2 Linggong Road, Gaoxinyuan District, DaLian, 116023, China, Lijun Sun, Haiyang Shi, Xiangpei Hu

This paper addresses the multi-compartment vehicle routing problem for oil products distribution with transshipment. A mixed distribution scheme combining separate distribution and co-distribution is proposed to reduce the total distribution cost. We solve the problem with the Clarke and Wright savings algorithm incorporating the exchange and insertion operators. Numerical results show that the mixed scheme is always better than the separate distribution used in practice. As a result, the mixed scheme is advisable in oil products distribution with transshipment.

#### 5 - Parallel-batching Scheduling: Impact of Adding Machine Capacity

Jun Xu, Northwestern Polytechnical University, Xi'an, China, Junqiang Wang

Scheduling performance can be improved with extra cost by resource augmentation such as adding machine capacity. This paper investigates the impact of adding machine capacity on the scheduling objective function. We measure such capacity impact by the ratio and give the bounds on the capacity impact for the problem to minimize the makespan and total completion time. Furthermore, to trade off gains in scheduling performance against the losses in adding machine capacity extra cost, we propose a cost-effective approximate algorithm and analyze the corresponding worst-case ratio.

## ■ MD52

North Bldg 231C

### Joint Session SMA/Practice Curated: Social Media Analytics and Business Value

Emerging Topic: Social Media Analytics

Emerging Topic Session

Chair: Nohel Zaman, Blacksburg, VA, 24060, United States

#### 1 - Effective Text Mining Techniques for Understanding Employee Opinions

David Michael Goldberg, Virginia Tech, 880 West Campus Drive, Suite 1007, Blacksburg, VA, 24060, United States, Nohel Zaman

Employee satisfaction is a vital component of workplace culture, and it has substantial impacts in firm performance. In this work, we propose and compare several text analytics methods for understanding employee perceptions of their work environment using data from online discussions. These techniques will allow firms to understand nuanced employee perceptions and to pursue remediation if necessary.

#### 2 - The Effects of Online Consumer Reviews on Product Sales in Mobile Apps Industry: An Empirical Study

Zhilei Qiao, Virginia Institute of Technology, 880 West Campus Drive, Blacksburg, VA, 24061, United States

Prior studies show that online consumer reviews have significant impacts on consumers' adoption decisions and firms' sales. This study extends the previous research and examines the effect of online user reviews on new product sales in the mobile app industry. Our results show that the review valence has a significant positive effect on new paid products, whereas the review valence has a significant negative effect on free products. Furthermore, we find that in-app purchase option has a moderating effect on the relationship between review characteristics and product sales for free and paid products. These surprising results show that review ratings have strong persuasive effects on product sales.

#### 3 - Comparing Text Analytics Methods for Understanding Hotel Reviews

Nohel Zaman, Virginia Tech, 880 West Campus Drive, Suite 1007, Blacksburg, VA, 24060, United States, David Michael Goldberg

The hotel industry is rife with various service issues, which lead to dissatisfied customers. Online user-generated content presents firms with a valuable opportunity to collect business intelligence and to understand these problems. This study focuses on comparing the performance of text analytics for detecting these instances in online media and determining how best to analyze different types of consumer complaints.



## ■ MD53

North Bldg 232A

### Market Design

Sponsored: Auction and Marketing Design

Sponsored Session

Chair: Itai Ashlagi, Stanford University, Stanford, CA, 94305, United States

#### 1 - Centralized Admissions for Engineering Colleges in India

Yash Kanoria, Columbia Business School, 404 Uris Hall, New York, NY, 10027, United States, Surender Baswana, Partha Pratim Chakrabarti, Sharat Chandran, Utkarsh Patange

We designed and implemented a new joint seat allocation process for over 500 programs across 80 engineering colleges in India, including the Indian Institutes of Technology (IITs). Our Deferred Acceptance-based process overcomes a number of challenges. The joint seat allocation process has been successfully running since 2015, with a 70% reduction in vacancies at the IITs. Particular concerns have been (i) allocative efficiency and reducing vacancies due to students accepting a seat but then withdrawing or not reporting for classes, (ii) transparency, integrity and fairness, (iii) logistical simplicity for both candidates and institutes, and (iv) the incentive structure for candidates.

#### 2 - On the Competition Complexity of Dynamic Mechanism Design

Christos-Alexandros Psomas, Carnegie Mellon University, 5000 Forbes Avenue, GHC 9116, Pittsburgh, PA, 15213, United States, Siqi Liu

Consider the following problem: a monopolist is auctioning off  $m$  items in  $m$  consecutive stages to  $n$  interested buyers. A buyer realizes her value for item  $k$  in the beginning of stage  $k$ . How many additional buyers are necessary and sufficient for a second price auction at each stage to extract revenue at least that of the optimal dynamic auction? We prove that the number of additional buyers, i.e. the Competition Complexity, is at most  $3n - 1$  and at least linear in  $n$  - even when the buyers' values are correlated across stages, under a monotone hazard rate assumption on the stage (marginal) distributions.

#### 3 - Repeated Sales for Multiple Strategic Buyers

Emmanouil Pountourakis, University of Texas at Austin, 16 Bristol Street, Unit 3, Cambridge, MA, 02141, United States, Nicole Immorlica, Brendan Lucier, Sam Taggart

In a market with repeated sales of a single item to a single buyer, prior work has established the existence of a zero revenue perfect Bayesian equilibrium in the absence of a commitment device for the seller. We show that in fact almost any revenue can be achieved in equilibrium, but the zero revenue equilibrium uniquely survives natural refinements. However, this market failure depends crucially on the assumption of a single buyer. If there are multiple buyers, we construct an intuitive equilibrium for multiple buyers that survives our refinements, in which the seller obtains a constant factor of the per-round Myerson optimal revenue.

#### 4 - Maximizing Efficiency in Dynamic Matching Markets

Maximilien Burq, PhD Student, Massachusetts Institute of Technology, 77 Massachusetts Avenue, Cambridge, MA, 02139, United States, Itai Ashlagi, Patrick Jaillet, Amin Saberi

We study the finite horizon problem of matching agents who arrive at a marketplace over time and leave after  $d$  time periods. Each pair of agents can yield a different match value, and we study matching algorithms that perform well over arbitrary arrivals. Our main contribution is a  $1/4$ -competitive algorithm which randomly selects a subset of agents who will wait until right before their departure to get matched, and maintains a maximum-weight matching with respect to the other agents. We extend the model to the case with stochastic departures, and establish a  $1/8$ -competitive algorithm in this setting. Finally we show on real-world data that a modified version of our algorithm performs well in practice.

## ■ MD54

North Bldg 232B

### New Areas in Behavioral Operations

Sponsored: Behavioral Operations Management

Sponsored Session

Chair: Evgeny Kagan, Ann Arbor, MI, 48103, United States

#### 1 - Entrepreneurial Market Research - When Hypotheses Outnumber Samples

Evgeny Kagan, University of Michigan, Ross School of Business, 701 Tappan Ave, Ross School of Business, Office R5425, Ann Arbor, MI, 48103, United States, Stephen Leider, William S. Lovejoy

In "technology-push" (relative to "demand-pull") innovation, technology teams

often develop a new capability that may find voice in a range of industrial settings. However, the team may lack the marketing budget to explore each in great depth, or even all of them at any depth. We formulate a bandit model to study this problem and develop a novel approach to its resolution, which includes simulation, interpretation, communication and implementation of search strategies.

#### 2 - Effect of Flexibility on Consumption of Services

Rajiv Mukherjee, Southern Methodist University, 11113 New Orleans Dr, Frisco, TX, 75035, United States, Sreekumar R. Bhaskaran, Sanjiv Erat

In this paper, we experimentally investigate how flexibility in consumption interacts with the actual usage of a service by consumers. Subsequently, we study a firm's pricing and capacity planning decision under the presence of these effects. The results have interesting implications in industries where managing congestion is an important consideration.

#### 3 - The Effects of Mental Accounting on Project Management and Performance

Yael S. Grushka-Cockayne, Darden School of Business, University of Virginia, 100 Darden Boulevard, Charlottesville, VA, 22903, United States, Manel Baucells, Woonam Hwang

We consider a project manager who decides on the budget and the scope of a project, and must react to news as the project evolves, possibly revising the cost and scope. The project manager is likely to compare ongoing cost and scope to a baseline. When costs and benefits are dissociated in time—as is the case of a project—such comparisons give rise to a mental accounting process where costs and benefits are either mentally banked or amortized. We develop a stylized model capturing this process, and investigate the impact of loss aversion, reference-point updating, and narrow framing on a project manager's decisions and the project's financial performance.

#### 4 - From Noise to Bias in Linked Supply Chain Decisions

Jordan D. Tong, University of Wisconsin Madison, 975 University Ave, Room 4293, Madison, WI, 53706, United States, Daniel Feiler

We complement BOM research on random error by studying how noisy behavior plays out in linked decisions. In the choose-forecast-invest task combination, one must (a) choose which product to sell (b) make a demand forecast for the chosen product and (c) make an investment decision for the chosen product. Through behavioral models and lab experiments, we show how adding unbiased random noise to the process leads to systematic overinvestment. This bias arises due to the way that random noise filters through the linked decisions and statistical naivety on the part of the decision-maker. We show how some kinds of noise reduce the bias while others actually mitigate it, and test a debiasing technique.

## ■ MD55

North Bldg 232C

### Getting Funded by NSF: Proposal Preparation and the Merit Review Process

Emerging Topic: NSF

Emerging Topic Session

Chair: Irina Dolinskaya, National Science Foundation, 2415 Eisenhower Ave, Alexandria, VA, 22314, United States

#### 1 - Getting Funded by NSF: Proposal Preparation and the Merit Review Process

Irina Dolinskaya, National Science Foundation, 2415 Eisenhower Ave, Alexandria, VA, 22314, United States

So, you think you have a great research idea, now how do you get funding from the National Science Foundation (NSF) to do the work? A well-scoped and written proposal is instrumental to successful submission. This session targets junior faculty and researchers who might be new to NSF and describes detailed guidelines and practical advice for proposal preparation. The presenters will go over NSF review process and Intellectual Merit and Broader Impacts criteria, as well as share most common mistakes made by the PIs when submitting a proposal. Question-and-answer session will follow the presentation.

## ■ MD56

West Bldg 101A

### Medical Decision Analysis by Bonder Scholars

Sponsored: Health Applications

Sponsored Session

Chair: Pooyan Kazemian, Harvard Medical School, Boston, MA, 02114, United States

#### 1 - Ambulance Emergency Response Optimization in Developing Countries: Application

Justin James Boutilier, University of Toronto, 532 Palmerston Boulevard, Apartment 6, Toronto, ON, M6G 2P5, Canada, Timothy Chan

The lack of emergency medical transportation is viewed as the main barrier to the access and availability of emergency medical care in low and middle-income countries (LMICs). In this paper, we present a robust optimization approach to optimize both the location and routing of emergency response vehicles, accounting for uncertainty in travel times and spatial demand characteristic of LMICs. We then combine our robust optimization approach with two machine learning frameworks and real data from Dhaka, Bangladesh. The focus of this talk is to provide an in-depth investigation into three policy-related questions.

#### 2 - Trial Termination and Drug Misclassification in Sequential Adaptive Clinical Trials

Alba Rojas-Cordova, Southern Methodist University, Dallas, TX, 75219, United States, Ebru Korular Bish, Niyousha Hosseinichimeh

We examine the nature and implications of wrongly terminating the development of an effective candidate drug, which may lead to unrecoverable expenses, and unfulfilled patients' needs. To this end, we build a simulation model of a Phase 3 sequential adaptive trial, and focus on the continuation or termination decision at one of the planned interim analysis points, based on the feedback from the drug testing process. We examine the effects of imperfect information and the conditions that lead to drug misclassification by conducting an extensive Monte Carlo-style sensitivity analysis. Contrary to the literature's focus on false positives, our results suggest that false negatives can be more likely.

#### 3 - The Development and Validation of a New Microsimulation Model of Type 2 Diabetes

Pooyan Kazemian, Harvard Medical School, 50 Staniford Street, 9th Floor, Room 930B, Boston, MA, 02114, United States, Deborah Wexler, Naomi Fields, Robert Parker, Amy Zheng, Rochelle Walensky

We developed a novel microsimulation model of type 2 diabetes progression and outcomes using data from recent randomized clinical trials and cohort studies. We validated the model against outcomes from two clinical trials (ACCORD and VADT) using several statistical methods which demonstrate that our model can accurately predict clinical outcomes of patients with type 2 diabetes in the modern era. The model will be used to project long term clinical and economic outcomes of treatment interventions for type 2 diabetes.

#### 4 - Data-driven Optimization Models for Concussion Management Decisions

Gian-Gabriel P. Garcia, University of Michigan, Ann Arbor, MI, 48105, United States

Concussion is an emerging public health issue. Recent research has begun to illuminate the relationship between concussion and long-term consequences including cognitive impairment, neurodegenerative disease, and early onset dementia. Concussion management plays a critical role in long and short-term health outcomes for those with concussion. In this talk, we discuss how we apply data-driven optimization to address major challenges in concussion diagnosis and post-injury management.

## ■ MD57

West Bldg 101B

### Financial Incentives in Healthcare Delivery

Sponsored: Health Applications

Sponsored Session

Chair: Turgay Ayer, Georgia Institute of Technology, Atlanta, GA, 30332, United States

Co-Chair: Zhaowei She, Georgia Institute of Technology, Atlanta, GA, 30332, United States

#### 1 - Reference Pricing for Healthcare Services

Shima Nassiri, University of Michigan, Ross School of Business, 701 Tappan Avenue, Ann Arbor, MI, 48109, United States, Elodie Adida, Hamed Mamani

The traditional payment system between an insurer and hospitals does not incentivize hospitals to limit their prices and patient to choose less expensive providers, hence contributing to high insurer costs. Reference pricing (RP) has been proposed as a way to better align incentives and control rising costs. Under RP, the patient may be responsible for part of the cost if they select a high-price hospital. We propose a model to analyze the RP payment scheme that incorporates an insurer choosing the reference price, competing price-setting hospitals, and patients selecting a provider based on a multinomial logit choice model. Our goal is to understand how RP compares with the current payment system.

#### 2 - The Role of Non-clinical Workforce on Patient Service: Evidence from NHS Helpline

Bilal Gokpinar, UCL School of Management, 1 Canada Square (38th floor), Canary Wharf, London, E14 5AA, United Kingdom, Emmanouil Avgerinos

Healthcare organizations rely on a mix of clinical and non-clinical personnel in delivering health services. Although non-clinical workers are vital in many healthcare delivery settings today, their impact on efficiency and quality of patient service has not been examined in the operations management literature. In this study, making use of a novel dataset based on National Health Service (NHS)'s new 111 non-emergency helpline in England, we quantify and demonstrate trade-offs associated with employing non-clinical personnel in delivering patient service.

#### 3 - Pay-for-quality or Pay-for-selection? An Analysis of the Capitation Payment Models in Healthcare

Zhaowei She, Georgia Institute of Technology, 755 Ferst Drive NW, Main 346 B, Atlanta, GA, 30332, United States, Turgay Ayer, Daniel Montanera

Capitation payment models have been increasingly adopted by payers in U.S. healthcare markets during the past decade, as a remedy for fee-for-service (FFS) payment models. However, early empirical evidence found that Medicare Advantage (MA), the largest capitation program in the U.S., has been suffering from another kind of market failure: risk selection. While the existing literature attributes the observed risk selection in capitation programs primarily to imperfect estimation in risk adjustment, this paper discovers a new source of risk selection: Pay-for-Selection. We further conduct a difference-in-difference (DID) estimation to identify the pay-for-selection effect in MA market.

#### 4 - Why Is Cost at a Modern Indian Hospital Lower than at Well-managed US Peers?

Feryal Erhun, University of Cambridge, University of Cambridge, Trumpington Street, Cambridge, CB2 1AG, United Kingdom

Modern Indian hospitals attain lower cost of care while meeting US-equivalent quality accreditation standards. This is unsurprising because they pay far lower market prices for inputs to care. Whether their cost advantage is also attributable to care delivery methods that could be adopted by hospitals in the US remains unresolved and is the focus of this study.

## ■ MD58

West Bldg 101C

### Joint Session HAS/Practice Curated: Analytics and Optimization in Health Systems

Sponsored: Health Applications

Sponsored Session

Chair: Seyma Guven-Kocak, Georgia Institute of Technology, Atlanta, GA, 30340, United States

Co-Chair: Pinar Keskinocak, Georgia Institute of Technology, Atlanta, GA, 30332, United States

Co-Chair: Dave Goldman, Georgia Institute of Technology, Atlanta, GA, 30332-0205, United States

#### 1 - Pediatric Kidney Post-Transplant Survival Analysis and Risk Factor Identification

Yao Xie, Georgia Institute of Technology, 4049 Wieuca Road NE, Atlanta, GA, 30342, United States, Xi He, Pinar Keskinocak, Joel Sokol

We build statistical models that accurately predict the post-transplant survival functions for pediatric kidney transplant patients and identify the most important risk factors. The pediatric transplant recipients are less commonly studied in the existing literature, while models developed for the general transplant recipients are not applicable. We use a large-scale UNOS (United Network for Organ Sharing) dataset and apply statistical variable selection techniques, specifically the group lasso and the random forest variable importance, to identify the most important risk factors. We also successfully identify multiple subgroups where the survival characteristics are different.

## 2 - Optimizing Population Screening for Infectious Diseases. The Case of Sleeping Sickness Control in Congo

Harwin de Vries, INSEAD, Boulevard de Constance,  
Fontainebleau, 77210, France

Population screening by mobile units is crucial to control several infectious diseases. We consider the following planning problem: given a set of populations at risk, the expected evolution of the epidemic in these populations, and a fixed number of mobile units, which villages should be screened when? We present descriptive models for the development of the burden of disease over time which take screening explicitly into account, use these to develop and analyze several classes of planning policies, and numerically analyze them in the context of the control of the HAT disease in D.R. Congo.

## 3 - Individual Wait Time Estimation in the Organ Allocation System

Ana Maria Estrada Gomez, Georgia Institute of Technology,  
Atlanta, GA, United States, Kamran Paynabar

When a patient is offered an organ, he/she needs to decide whether to accept or decline it. This complex decision depends in part on the estimated wait time until the next organ offer and that organ's quality. Using a match-run database, we develop methods to predict the wait time for an organ (liver, kidney, lung, heart) offer of a desired quality, given the patient's characteristics and compare our estimates to those provided by UNOS.

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oris Van de Klundert, Albert P M Wagelmans

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## 3 - Individual Wait Time Estimation in the Organ Allocation System

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## 4 - A Scan Statistic for Disease Detection

Dave Goldsman, Georgia Institute of Technology, School of ISyE,  
Atlanta, GA, 30332-0205, United States, Ignacio Erazo

Consider a square containing a number of uniformly distributed points. We use analytical methods and Monte Carlo simulation to obtain the distributions of certain scan statistics, for instance, the maximum number of points contained in a smaller square as it sweeps through the original square. These distributional results lead to statistical tests to detect the occurrence of a significant event such as a disease outbreak. Several examples illustrate our method's efficacy, statistical power, and ease of use.

## MD59

West Bldg 102A

## Methods for Decision Making in Healthcare

Sponsored: Health Applications

Sponsored Session

Chair: Vishal Ahuja, Southern Methodist University, Dallas, TX, 75275, United States

## 1 - Using a Deep Learning Algorithm to Quantify Common Barriers to Discharge

Taghi Khaniyev, MIT Sloan School of Management, Cambridge,  
MA, United States, Dominic Breuer, Kyan Safavi,  
Ana Cecilia Zenteno, Mark Seelen, Jonathan Zanger,  
Bethany Daily, Peter Dunn, Retsef Levi

Hospital congestion is caused among other factors by an imbalance of the timing of patient admissions and discharges. We implemented a real-time clinical support tool to predict next-day's surgical patient discharges based on previous patients' recovery care paths at a large academic medical center. Further, we analyzed mismatches between predicted and actual discharges to identify areas for improvement in the discharge process and to enhance the accuracy of the tool. Results show that the top 10 patients predicted to leave are discharged 81% of the time within 24 hours. Mismatches occurred without clinical reason 45% of the time and were due to clinical practice variation 25% of the time."

## 2 - "Wait and then Hurry Up" – the Effect of Flexible Service Rates in Appointment Scheduling Systems

Aditya Jain, Baruch College, Zicklin School of Business, 55  
Lexington Ave, Suite 9-240, New York, NY, 10010, United States,  
William P. Millhiser

Recent empirical evidence suggests that ambulatory care healthcare workers vary service rates in response to time of day and queue length. In this paper, we explore a theoretical justification of this behavior using trade-off between waiting and processing costs and analyze its implications for established appointment systems, and how they should be adapted.

## 3 - A New Patient Trajectory Simulation Method for Staffing in Care Coordination Programs

Ekin Koker, University of Massachusetts, Mechanical and  
Industrial Engineering, 160 Governors Drive, Amherst, MA,  
01003, United States, Rebecca Castonguay, Hari Balasubramanian,  
Zachary Martinez, Aaron Truchil

Care Coordination programs intended to improve outcomes and lower cost of care for patients with complex health and social needs have proliferated in recent years. Staff encounters with patients in these programs can be modeled as a trajectory, each encounter marked with a staff type, duration and a timestamp from enrollment date. Using encounter data from a care coordination program, we simulate different realizations by sampling patient trajectories randomly without replacement, allowing for a constant and a Poisson patient arrival rate. We present our findings and offer insights for healthcare organizations looking to start care coordination programs.

## 4 - Optimization Approaches for Concussion Management Decisions

Gian-Gabriel Garcia, Mariel Sofia Lavieri

We apply optimization for concussion management decisions.

## MD60

West Bldg 102B

## Scheduling and Resource Allocation in Health Systems

Sponsored: Health Applications

Sponsored Session

Chair: Pinar Keskinocak, Georgia Institute of Technology, Atlanta, GA, 30332, United States

Co-Chair: Seyma Guven Kocak, Georgia Tech, Atlanta, GA, United States

## 1 - Staff Planning with Cost Estimation and Optimization

Kumar Rajaram, University of California-Los Angeles, Anderson  
School, 110 Westwood Plaza, Los Angeles, CA, 90095-1481,  
United States, Sandeep Rath

We consider the staff planning problem of anesthesiologists which consists of determining how many anesthesiologists have to be on regular duty and on call each day. We model this problem as a two-stage integer stochastic dynamic program. We use structural estimation to assess the implicit costs in this model. We develop a solution algorithm, and test the model with real data from the UCLA medical center.

## 2 - Home Health Care Routing and Scheduling with Continuity of Care

Seyma Guven-Kocak, Georgia Institute of Technology,  
1235 Parkway Circle N, Atlanta, GA, 30340, United States,  
Aliza R. Heching, Pinar Keskinocak, Alejandro Toriello

This work addresses a real-world home health care routing and scheduling problem (HHCRRSP) faced by a home care agency in the U.S. In home health care scheduling, there is a desire to retain consistency with respect to the nurses servicing each patient, which is referred to as continuity of care. In order to handle this requirement, we propose a dynamic approach and present two different methods to solve the problem on a daily basis: a MIP with approximations and a variant of a petal heuristic. We aim to quantify and control the deviation from the existing schedule in place, so that some of the assignments are retained in the new schedule. We discuss the performance and computational efficiency of these methods.



### 3 - Consistent Nursing Staff Planning Under Heterogeneous Service Demand

Nan Kong, Purdue University, 206 South Marting Jischke Drive,  
Biomedical Engineering, West Lafayette, IN, 47906-2032,  
United States, Mingyang Li, Mingzheng Wang

The aging population in the U.S. demands a significant amount of long-term care (LTC) services. As major LTC service providers, nursing homes (NHs) are responsible for caring the frailest population of elderly adults with 24/7 formal assistance for a variety of services and supports. To improve the quality of care and realize resident-entered NH care, we develop accurate predictive models for characterizing complex service demand of individual NH residents. We also develop more proactive and cost-effective NH staff optimal planning model with a stochastic programming approach.

### 4 - Integrating New Testing Mechanisms Into Emergency Department Workflow

Jonathan Helm, Arizona State University, W.P. Carey School of  
Business, 300 E. Lemon St, Tempe, AZ, 85287, United States,  
Zhongjie Ma, Pengyi Shi, H. Sebastian Heese

In medical research, new diagnostic tests are developed and evaluated solely on their efficacy in detecting an illness. However, ignoring the workload impact of introducing new tests into existing workflow can create barriers to adoption, particularly in busy units e.g. Emergency Department (ED). In collaboration with an ED physician, we develop a framework for evaluating the workload impact of adopting new tests to bridge the gap between medical research and clinical workflow. Our queueing framework is applied to a new test, D-dimer, for detecting Pulmonary Embolism in EDs to understand what characteristics make adopting a test feasible and how to best integrate the D-dimer into the ED workflow.

### 5 - An Optimization Model for Collecting and Distributing Blood Products

Ayca Erdogan, San Jose State University, Davidson College of  
Engineering, Industrial and Systems Engineering, San Jose, CA,  
95192, United States, Nazanin Nader

We present an integer programming model to find the optimal routes for a blood donation center. The model minimizes the total travel time for vehicles that collect donated blood from donation locations &lt; distribute processed blood to several hospitals, considering lateness thresholds in order to minimize the blood wastage.

## ■ MD61

West Bldg 102C

### Telecommunications Optimization Modeling

Sponsored: Telecommunications and Network Analytics

Sponsored Session

Chair: Eli Olinick, Southern Methodist University, Dallas, TX, 75275-0123, United States

#### 1 - Big Data Processing Platform for Healthcare Applications

Albena Mihovska, Aarhus University BSS, Birk Centerpark 15,  
Herning, 7400, Denmark

This work proposes a novel conceptual approach to IoT/cloud convergence and its implementation in healthcare application platforms. The proposed platform allows for the collection, exchange and processing of healthcare related data without distorting the quality of the collected data and without compromising the personal aspects of the processed data; based on an elastic from point of view of security and performance wireless network and a distributed processing platform and their seamless integration. To this end the work addresses the processing of multiple data streams, the design of the interfaces between the sensing and cloud environments; and the secure communications between the IoT devices and big data applications.

#### 2 - Impact of Telecommunications on Household Finances

Stanko Dimitrov, Associate Professor, University of Waterloo,  
200 University Avenue West, Waterloo, ON, N2L 3G1, Canada,  
Brian Paul Cozzarin

Telecommunications have positive impacts such as reduced cost of data delivery. However, there may be negative, financial, impacts. Using a Canada wide survey data, we find that using online banking causes an increase in personal debt-to-income ratio of 1.42 dollars more for every dollar earned on average, relative to not banking online. Our finding is supported and contributes to work in telecommunications in retail. The findings hopefully inform consumers' actions when deciding to engage in online banking, as well as banks when assessing the risk of its customers.

### 3 - Determining Queue Assignment and Threads in a Multi-Queue Multi-Threaded System

Adam Colley, Southern Methodist University, Dallas, TX, United States, Eli Olinick

We present a methodology for performance tuning an online business-to-business integration (B2BI) service that manages a system of G/G/1 queues running on a multicore computer processing unit (CPU), or network of CPUs. Tuning consists of optimizing the assignment of processes to priority queues, the assignment of threads to queues, and the relative queue weights. We demonstrate the methodology, and analyze its performance, on a real-world application of the IBM B2B Integrator.

## ■ MD62

West Bldg 103A

### Interfaces Between Optimization and Machine Learning

Sponsored: Data Mining

Sponsored Session

Chair: Velibor Mistic

#### 1 - Discovering Optimal Policies: A Pattern Recognition Approach to Model Analysis

Fernanda Bravo, UCLA Anderson School of Management, 110  
Westwood Plaza, B4.11, Los Angeles, CA, 90024, United States,  
Yaron Shaposhnik

We study the application of machine learning algorithms to derive insights and identify structural properties of mathematical models. As a proof of concept, we apply the proposed framework to core optimization problems, such as inventory replenishment, queueing admission control, revenue management and multi-armed bandit problems. We formulate classification and regression problems and show how numerically obtained optimal solutions can be used to identify structural properties, derive compact representations and interpret complex policies.

#### 2 - Optimization of Tree Ensembles

Velibor Mistic, UCLA Anderson School of Management,  
110 Westwood Plaza, Suite B406, Los Angeles, CA, 90095,  
United States

Tree ensemble models such as random forests and boosted trees are often used to predict the effect of different decisions. While such models are widely used for predictions, little is known about how to use them for effective decisions. In this talk, we consider the problem of finding a decision that is optimal with respect to a tree ensemble model. We formulate this problem as a mixed-integer optimization model and present theoretical results on its structure. We test our method on real data sets, including two case studies in drug design and customized pricing, and show that it can efficiently solve large-scale instances to near or full optimality, outperforming heuristic solutions.

## ■ MD63

West Bldg 103B

### Representation Learning for Unstructured Data

Sponsored: Data Mining

Sponsored Session

Chair: Mustafa Gokce Baydogan, PhD, Bogazici University, Bogazici Universitesi, Endustri Muh. Bolumu, Istanbul, 34342, Turkey

#### 1 - A Dissimilarity Regularization Approach for Distinct Feature Learning with Autoassociative Neural Networks

Phillip Howard, Intel Corporation, 5000 W. Chandler Blvd,  
Chandler, AZ, 85226, United States, Daniel Apley, George Runger

Autoassociative neural networks (ANNs) are useful for performing dimensionality reduction and have been proposed as a nonlinear extension of principal component analysis. While ANNs can learn complex nonlinear representations of high-dimensional data, they also have a tendency to extract repetitive features which are difficult to interpret. In this work, we present a new dissimilarity regularization method for encouraging the features learned by ANNs to be distinct. We demonstrate the effectiveness of our method for learning distinct

feature representations from both simulated and real data sets.

## 2 - Time Series Dimensionality Reduction Using Convolutional Recurrent Neural Networks

Maziar Kasaei Roodsari, Arizona State University, Tempe, AZ,  
United States, Sangdi Lin, George Runger

As huge volume of time series data is collected from various wearable devices and sensors in real-life, we are facing challenges in the storage, analysis, and visualization of time series data. An effective dimensionality reduction method for time series data is an important step towards solving these challenges. In this presentation, we discuss a novel deep learning model for time series dimensionality reduction which utilizes both convolutional neural networks and recurrent neural networks. The proposed model not only achieves low reconstruction error, but also generates discriminative features for future decision making.

## 3 - Ensemble-based Fast Shapelet Approximation

Berk Gorgulu, Bogazici University, Istanbul, Turkey,  
Mustafa Gokce Baydogan, Gonenc Yucel

Nearest-neighbor (NN) classifiers are widely used for classification of time series (TS) because of their simplicity. Recent TS classification methods focus on discovering discriminative subsequences, namely shapelets, to avoid problems with NN classifiers. Instead of pairwise distance calculations between the whole TS, shapelet-based approaches map TS to a feature vector based on the existence of the shapelets. We propose Ensemble-based Fast Shapelet Approximation (EFSA) that utilizes ensembles of regression trees to learn a piecewise approximation for shapelet identification in a supervised manner. Experiments show that EFSA yields fast and competitive results on benchmark datasets.

## MD64

West Bldg 104A

### Joint Session DM/Practice Curated: Data Science for Food and Agriculture

Sponsored: Data Mining

Sponsored Session

Chair: Durai Sundaramoorthi

#### 1 - Optimal Control in Dynamic Food Supply Chain Under Service Level Constraints

Ashton Kappelman, Kansas State University, 2061 Rathbone Hall,  
1701B Platt St., Manhattan, KS, 66506, United States,  
Ashesh Kumar Sinha

We consider a dynamic food supply chain with multiple suppliers and service level constraints. We propose an integrated approach that involves developing a Bayesian network to analyze the interaction of process parameters of suppliers on the service levels of the end product, and involves stochastic optimization models to provide insights on the structure of the optimal policy comprising of supplier at each level their process parameters.

#### 2 - Predictive Analytics and Vehicle Routing for an Urban Food Delivery Platform

Alexander Hess, PhD Student, WHU - Otto Beisheim School of  
Management, Burgplatz 2, Vallendar, 56179, Germany

This talk illustrates the application of predictive analytics in conjunction with vehicle routing for an urban food delivery platform. In particular, we show how more accurate forecasts achieved with machine learning algorithms lead to an improved routing. This in turn lowers the need for capacity in vehicles.

## MD65

West Bldg 104B

### Data Science and Artificial Intelligence II

Sponsored: Data Mining

Sponsored Session

Chair: Shengfeng Chen, Western Michigan University, Kalamazoo, MI, United States

#### 1 - Target-driven Navigation for Multi-robot via Deep Reinforcement Learning

Mengqi Hu, University of Illinois at Chicago, 842 W. Taylor Street,  
MC 251, 2039 ERF, Chicago, IL, 60607, United States, Zishun Yu

Multiple unmanned ground vehicle (UGV) navigation has attracted greater attention. In this research, we propose a multi-agent deep deterministic policy gradient (DDPG) model for multi-UGV navigation where the UGVs should move to their target points as fast as possible without collision with obstacles. DDPG is a model-free actor-critic algorithm for continuous control problem. In this model, we directly define the system state as a 1,500x3 matrix using data collected from

LiDAR installed on UGVs and actions as the angular and linear velocities. The experimental results demonstrate that the DDPG algorithm shows superior performance compared to state-of-the-art navigation algorithms.

#### 2 - Improving Berth Schedule Efficiency via Evolutionary Algorithms with Efficient Parameter Control

Maxim A. Dulebenets, Florida A&M University-Florida State  
University, Tallahassee, FL, 32311, United States,  
Masoud Kavooosi, Junayed Pasha, Olumide Abioye

This study presents a self-adaptive Evolutionary Algorithm for the berth scheduling problem, where the crossover and mutation probabilities are encoded in the chromosomes and evolve throughout the algorithmic run. Computational experiments are undertaken to assess performance of the developed algorithm against the alternative Evolutionary Algorithms, which rely on the deterministic parameter control, adaptive parameter control, and parameter tuning strategies respectively. Results show superiority of the self-adaptive Evolutionary Algorithm over the alternative algorithms.

#### 3 - Production Planning Using Reinforcement Learning

Karthick Gopalswamy, PhD Student, North Carolina State  
University, Raleigh, NC, 27606, United States

We consider the problem of finding optimal release plans for a production system under congestion given deterministic demand and random processing time. The problem is formulated as a model-free simulation based Reinforcement Learning (RL) problem. We outline the methodology and provide computational results comparing the operational costs of RL based algorithm and a simulation optimization algorithm.

#### 4 - An Image Based Deep Convolutional Neural Network for Industrial Product Defect Detection

Shengfeng Chen, Western Michigan University, 1903 Western  
Michigan Avenue, Kalamazoo, MI, 49008, United States,  
Lin Cheng

Machine vision system are increasingly being used in industrial product defect detection. Traditional methods work well only under certain conditions with many requirements. We propose a deep convolutional neural network (CNN) structure that can efficiently and reliably extract powerful features for defect detection. With only four deep convolution layers, the proposed model can detect tiny changes in the image with a small training dataset of less than 400 prior knowledge of images. Experimental results achieve a high accuracy of near 100 percent.

## MD66

West Bldg 105A

### Text Mining in IS Research

Sponsored: Artificial Intelligence

Sponsored Session

Chair: Jingjing Li

#### 1 - More than the Quantity: Estimating the Value of Editorial Review for UGC Platform

Yipu Deng, Purdue University, 2826 Peachleaf Drive, West  
Lafayette, IN, 47906, United States, Jinyang Zheng,  
Warut Khern-am-nuai, Karthik Kannan

This work studies the implication of an editorial review platform where a review platform starts to supplement the user-generated content on its website with editorial reviews that are written by the platform. Our research question is whether platform-generated content (i.e., editorial reviews) influences subsequent user-generated content (i.e., user reviews) both in terms of the quantity and quality. Our analysis suggests that editorial reviews have a positive net effect on subsequent user reviews in general. Specifically, users post more reviews for restaurants that have editorial reviews. Moreover, these user reviews tend to be longer and resemble editorial reviews in respect of quality.

#### 2 - Social CRM and Brand Crisis: A Natural Experiment from Airline Industry

Ramah Al Balawi, University of Illinois at Chicago, 601 S. Morgan  
St, Chicago, IL, 60607, United States, Yuheng Hu, Liangfei Qiu

This work aims to understand how brands change their engagement strategy in response to a crisis. By using a recent crisis of United Airlines, we collected Twitter data about United Airline customer service and find that United Airline strategically changes its social media policy when engaging with its customers.

### 3 - Strategically Combining Human Intelligence and Machine Intelligence in Clinical Decision Support Systems

Long Xia, Virginia Polytechnic Institute and State University, 880 W. Campus Drive, 2069 Pamplin Hall, Blacksburg, VA, 24061, United States

Healthcare is a domain in which experts' knowledge plays significant roles in a variety of tasks. This is one of reasons why solely using deep learning models often could not achieve satisfactory results. We adopted the crowd wisdom concept and proposed a framework to strategically combine human intelligence and machine intelligence in the context of clinical decision support systems. Our experimental evaluations demonstrate that our approach can make a significant performance improvement compared with existing approaches.

## ■ MD67

West Bldg 105B

### Causal Inference and Machine Learning

Sponsored: Information Systems

Sponsored Session

Chair: Wei Chen, University of Arizona

#### 1 - Deep Learning for Overweight Prediction on Twitter

Luwen (Vivian) Huangfu, University of Arizona, Tucson, AZ, United States

Overweight is epidemic in the United States and elsewhere in the world, which is serious and costly nowadays. However, it's humans' nature to store energy in case of famine, causing overweight outbreaks on a large scale due to the increased availability and consumption of high-calorie food. We are motivated to study overweight based on the language of food on Twitter using deep learning. Our result reached a good performance, with remarkable improvement when comparing with the benchmark, revealing that deep learning can be utilized to monitor overweight issues from Twitter.

#### 2 - An Exact and Robust Conformal Inference Method for Counterfactual and Synthetic Controls

Yinchu Zhu, University of Oregon, Eugene, OR, 97401, United States, Kaspar Wuthrich, Victor Chernozhukov

We introduce new inference methods for counterfactual and synthetic control methods for evaluating policy effects. Our inference methods work in conjunction with many modern and classical methods for estimating the counterfactual mean outcome in the absence of a policy intervention. Specifically, our methods work together with the difference-in-difference, canonical synthetic control, constrained and penalized regression methods for synthetic control, factor/matrix completion models for panel data, interactive fixed effects panel models, time series models, as well as fused time series panel data models.

#### 3 - Completing the Online-offline Circle at the Last-mile: A Large Randomized Field Experiment

Tianshu Sun, University of Southern California, 3670 Trousdale Parkway, Bridge Hall, BRI 310B, Los Angeles, CA, 90089, United States, Rongqing Han, Leon Zhu, Lixia Wu

Pickups stations have the promise to reduce the logistic cost of last-mile delivery in E-commerce. At the same time, they also serve as an ideal touchpoint to connect customers and brands in the physical world and can bring benefits to the platform. In this study, we examine whether E-commerce platforms can take advantage of pick-up stations and complete the online-offline circle at the last mile. We design a large experiment with Alibaba and examine 1) Whether platforms can use online intervention to elicit customers to utilize offline pickup service (Online-to-Offline) and 2) Whether offline interaction with products can encourage customers to engage with brands and platform (Offline-to-Online).

#### 4 - Nowcasting the Local Economy: Using Yelp Data to Measure Economic Activity

Hyunjin Kim, Harvard Business School, 84 HBS Mail Center, MA, Boston, MA, 02163, United States, Edward L. Glaeser, Michael Luca

Can new data sources from online platforms help to measure local economic activity? In this paper, we present evidence that Yelp data can complement government surveys by measuring economic activity in close to real-time, at a granular level, and across geographic scale. Changes in the number of businesses reviewed on Yelp can generate an algorithm that explains 29.2 percent of the residual variance in changes in the number of establishments in County Business Patterns (CBP), after accounting for lagged CBP data. The algorithm is more accurate for denser, wealthier, and more educated ZIP codes.

## ■ MD68

West Bldg 105C

### Joint Session QSR/Practice Curated: High Dimensional Data Analysis and its Applications in System Informatics and Control

Sponsored: Quality, Statistics and Reliability

Sponsored Session

Chair: Mostafa Reisi Gahrooei, Georgia Tech, 755 Ferst Dr, Atlanta, GA, 30318, United States

Co-Chair: Kamran Paynabar, Georgia Tech, Atlanta, GA, 30332, United States

#### 1 - Image Based Online Defect Detection and Closed Loop Quality Control for Additive Manufacturing Processes

Chenang Liu, Virginia Tech, VA, United States, Zhenyu Kong

A major challenge in additive manufacturing (AM) is how to ensure product quality and consistency by eliminating defects. To address this challenge, this work develops an image-based closed-loop quality control system for the fused filament fabrication (FFF) process. This system consists of a real-time image acquisition device, a high accuracy image-based classification algorithm to monitor the status of surface quality, and a PID-based controller for defects mitigation. The case studies based on actual AM experiments demonstrate the effectiveness of the proposed method.

#### 2 - Multiple Tensor-on-tensor Regression

Mostafa Reisi Gahrooei, Georgia Tech, Atlanta, GA, 30318, United States

In recent years, measurement or collection of heterogeneous sets of data such as those containing scalars, waveform signals, images, and even structured point clouds, has become more common. This work addresses the problem of estimating a process output, measured by a scalar, curve, image, or structured point cloud by a set of heterogeneous process variables such as scalar process setting, profile sensor readings, and images.

#### 3 - An Efficient Monitoring of Variance in High-dimensional Process

Sangahn Kim, Rutgers University, 96 Frelinghuysen Road, Room 201, Piscataway, NJ, 08854, United States, Galal M. Abdella, Jinho Kim, Khalifa M. Al-Khalifa, Myong Kee Jeong, Abdelmagid S. Hammuda

In high-dimensional processes, monitoring process variability is considerably difficult due to a large number of variables and the limited number of samples. Monitoring changes in the covariance matrix is often used for monitoring process variability under the assumption that only a few elements in the covariance matrix are changed simultaneously. In this presentation, we propose a control chart based on an adaptive LASSO-thresholding for monitoring process variability and illustrate the advantages of the proposed method through simulated and real data from both semiconductor industry and high-dimensional milling process.

#### 4 - Learning Inter-layer Bonding Effects in 3D Printing through a Convolution Formulation

Yuanxiang Wang, University of Southern California (USC), CA, United States, Qiang Huang

Geometric accuracy control is critical for additive manufacturing (AM) or three-dimensional (3D) printing. The prediction and control of out-of-plane deviation of 3D printed products needs the understanding of inter-layer bonding effects. This work presents a convolution formulation for the inter-layer interactions to predict out-of-plane shape deviations. Experimental investigation using stereolithography process validates the proposed model.



## ■ MD69

West Bldg 106A

### Image-Based Statistical Process Control in Advanced Manufacturing

Sponsored: Quality, Statistics and Reliability

Sponsored Session

Chair: Anh Bui, Northwestern University, Evanston, IL, United States

#### 1 - Tomography Reconstruction with Sparsity Regularization for Accurate Measurement of Nanoproduct Dimensions in 3D

Chen Mu, FAMU-FSU College of Engineering, Tallahassee, FL, United States, Chiuwoo Park

The dimensions of nanomaterials often determine their properties and functionalities. Therefore, measuring the dimensions of nanomaterial products is an essential step for quality assurance of nanomaterial production. This talk is concerned with how to measure the dimensions of nanomaterial products in 3d with a series of its low dimensional projection images from different projection angles, which is well known as a tomography reconstruction problem. We presents a novel tomography reconstruction approach that combines the computational advantage of the existing filtered back projection approach and the precision advantages of the iterative optimization approach.

#### 2 - Image Comparison for Online Image Monitoring

Peihua Qiu, University of Florida, CTRB, 5th Floor, 2004 Mowry Road, Gainesville, FL, 32610, United States

Images are commonly used for quality control purposes. If the quality of the products is good, then their images should be all similar to the image of a good-quality product. So, comparison of images is a fundamental task in image-based quality control. This problem is complicated because of noise and geometrical mismatch between images. In this talk, we present an effective method for detecting difference between two images of products, and our proposed method can accommodate both noise and geometric mismatch mentioned above. Theoretical results and numerical examples show that it can work effectively in applications. This is a joint research with Dr. Long Feng.

#### 3 - Statistical Modeling and Analyzing Methods for Dynamic Nanomaterial Video Data

Yanjun Qian, Virginia Commonwealth University, 1015 Floyd Ave, Room 4134, Richmond, VA, 23220, United States

A large amount of nanomaterial video data has been collected by transmission electron microscopes (TEM). To model a nanoparticle growth process from such videos, we develop dynamic nonparametric models for time-varying probability density functions (pdfs) estimation. Unlike simple statistics, a pdf contains fuller information about the nanoscale objects of interests. Characterizing the dynamic changes of the pdf as the nanoparticles are growing into different sizes, the proposed nonparametric methods are capable of analyzing an in situ TEM video to delineate growth stages in a retrospective analysis or tracking the nanoparticle growth process in a prospective analysis.

#### 4 - Identifying Variation Patterns in Stochastic Textured Surface Data

Anh Tuan Bui, Northwestern University, Evanston, IL, 60208, United States, Daniel Apley

Existing methods for understanding manufacturing variation in multivariate or profile data are inapplicable for stochastic textured surface data. A primary challenge is the lack of an existing measure of the dissimilarity or distance between surface samples, due to their stochastic nature. We propose a pairwise dissimilarity measure and then use manifold learning on these dissimilarities to discover a low-dimensional parameterization of the surface variation patterns. Visualizing how the surfaces change as the manifold parameters are varied helps build an understanding of the physical nature of each variation pattern, which we demonstrate with real textile and simulation examples.

## ■ MD70

West Bldg 106B

### Joint Session DEA/Practice Curated: Applications in DEA

Emerging Topic: Productivity, Efficiency and Data Envelopment Analysis

Emerging Topic Session

Chair: Kankana Mukherjee, Babson College, Wellesley, MA, 02481, United States

#### 1 - Hospitals Efficiency Redux: The Role of Medical and Surgical Research

Antonio Garcia Romero, Assistant Professor, IE Business School, Maria de Molina 31 Bis, MADRID, 28006, Spain, Josep A. Tribo, Alvaro Escribano

DEA methods have been widely applied to the analysis of hospitals' efficiency.

However, there is little empirical evidence showing how the research conducted in hospitals can affect their outcomes. The structure of hospitals is a two-stage network process. Therefore, we use two-stage DEA methods for evaluating the performance in a sample of 189 Spanish hospitals over the period 1996-2009. We use the Malmquist productivity index for estimating the changes in efficiency since we use a longitudinal database. We measure the efficiency on several outcomes (i.e., the average length of stay or mortality rate. We measure the hospitals' research activity by using a set of bibliometric indicators.

#### 2 - Labor-cost Efficiency with Indivisible Outputs and Inputs: A Study of Indian Bank Branches

Kankana Mukherjee, Babson College, 231 Forest Street, Babson Park, MA, 02457, United States, Subhash C. Ray, Abhiman Das

This study uses Data Envelopment Analysis to examine the efficiency of branches of a major Indian public sector bank across four large metropolitan cities. We model branch operations following the production approach and introduce several methodological extensions to account for the product mix of branches in creating the efficient cost frontier. Overall, Chennai branches are found to be the most efficient. Across the three types of labor, attaining efficiency in the number of clerks would have the highest impact in terms of cost savings.

#### 3 - Predicting Corporate Failure for Non-Manufacturing Firms - DEA SBM

Joseph C. Paradi, Professor Emeritus, University of Toronto, 200 College Street, College St, Toronto, ON, M5S3E5, Canada

Slacks-Based DEA Model is used to predict corporate failure of non-manufacturing companies. The benchmark was the Altman Z" model. Others used DEA models (BCC) to using Altman's original asset-dominated Z-score model. Here, non-manufacturing firms were examined without their asset size. Data from non-manufacturing companies that filed for bankruptcy between 2000 and 2006 for up to five years before bankruptcy. Non-bankrupt companies were matched these, using SIC codes. Altman's model classified more companies as bankrupt than DEA, whereas DEA classified more as non-bankrupt. This indicated that bankruptcy could be predicted without the use of total assets or liabilities as variables.

## ■ MD71

West Bldg 106C

### Decision Diagram Approaches for Optimization

Sponsored: Computing

Sponsored Session

Chair: Merve Bodur, University of Toronto, 5 King's College Rd., Toronto, ON, M5S 3G8, Canada

#### 1 - Dexter: A Global Solver Based on Decision Diagrams

Danial Davarnia, Carnegie Mellon University, Pittsburgh, PA, United States, Christian Tjandraatmadja, Willem-Jan Van Hoeve

We develop a branch-and-cut technique to solve integer nonlinear programs, where the cuts are derived from the decision diagram representation of the model. The graphical structure of decision diagrams allows for specialized branching schemes that improve the relaxation by refining infeasible integer points, while benefiting from tighter representation due to the domain reduction. Such a modification of decision diagrams is efficient through branch-and-bound. We introduce a solver designed based on this approach. We conclude with computational results.

#### 2 - A Binary Decision Diagram Based Algorithm for Solving a Class of Binary Two-stage Stochastic Programs

Leonardo Lozano, University of Cincinnati, Cincinnati, OH, 45219, United States, Cole Smith

We consider a class of two-stage stochastic integer programming problems with binary variables in both stages, for which the second-stage variables belong to the intersection of sets corresponding to first-stage binary variables that equal one. Our approach uncovers strong dual formulations to the second-stage problems by transforming them into dynamic programming (DP) problems parameterized by first-stage variables, formed using of binary decision diagrams, which then yield traditional Benders inequalities that can be strengthened based on observations on the structure of the underlying DPs. We test our approach on a set of stochastic traveling salesman problems.

#### 3 - Network-based Approximate Linear Programming for Discrete Optimization

Andre Augusto Cire, University of Toronto-Scarborough, Department of Management, UTSC, 1265 Military Trail, Toronto, ON, M1C-1A4, Canada, Selvaprabu Nadarajah

We present a new hierarchy of approximate linear programming methods for a general class of discrete optimization problems. Our basis functions, in particular, are composed of network-based approximations for the problem, such as those derived from state-space relaxations and decision diagrams. Moreover, we exploit the network structure to iteratively construct a sequence of approximate linear programs with improving bounds that converge to the optimal solution value of the original problem. A numerical evaluation is discussed on challenging discrete optimization problems arising in practice.

#### 4 - Network Models for Multiobjective Discrete Optimization

Merve Bodur, University of Toronto, 5 King's College Rd., Toronto, ON, M5S 3G8, Canada, David Bergman, Andre Augusto Cire, Carlos Henrique Cardonha

We propose a novel framework for solving multiobjective discrete optimization problems with an arbitrary number of objectives. Our framework formulates these problems as network models, in that enumerating the Pareto frontier amounts to solving a multicriteria shortest path problem in an auxiliary network. We design tools and techniques for exploiting the network model in order to accelerate the identification of the frontier. We show that the proposed framework yields orders-of-magnitude performance improvements over existing state-of-the-art algorithms on four problem classes containing both linear and nonlinear objective functions.

## ■ MD72

West Bldg 211A

### Joint Session Wagner/Practice: Daniel H. Wagner Prize for Excellence in Operations Research Practice I

Emerging Topic: Daniel H. Wagner Competition

Emerging Topic Session

Chair: Patricia Neri, SAS Institute, Inc., 104 Grandtree Ct., Cary, NC, 27519, United States

#### 1 - Combinatorial Exchanges for Trading Fishery Access Rights

Martin Bichler, Technische Universität München, Department of Informatics, Boltzmannstr. 3, Munich, 85748, Germany, Douglas Ferrell, Jacob K. Goeree

Overfishing is a prime environmental concern. Catch share systems have recently been shown to be effective tools to combat overfishing. Yet, the allocation of catch shares has always been a challenging policy problem. There is an active discussion about market-based solutions for the allocation and re-allocation of fishery shares. Unfortunately, until yet there have not been adequate market designs to address the specific requirements in these markets. The recent subsidized share trading market in New South Wales (NSW) is a first-of-a-kind market design for the reallocation of catch shares and the largest combinatorial exchange to date. The market design needed to address several non-standard requirements, most importantly the lack of participation and fair payments. While these features were crucial for the adoption of the proposed design, they led to computationally challenging allocation and pricing problems. The implemented exchange illustrates how computational optimization and market design can provide new policy tools, able to solve complex policy problems considered intractable only a few years ago. The exchange operated from May to July 2017 and effectively reallocated shares from inactive fishers to those who needed them most. It can provide a template for the reallocation of catch shares in other fisheries world-wide as well.

#### 2 - Collaborative Human-UAV Search and Rescue for Missing Tourists in Nature Reserves

Yu-Jun Zheng, Hangzhou Normal University, Hangzhou, China, Wei-Guo Sheng, Yi-Chen Du, Hai-Feng Ling

The use of unmanned aerial vehicles (UAVs) is becoming commonplace in search and rescue tasks in complex terrains. In the literature, there are a number of studies on UAV search with the objective of minimizing search time and/or maximizing detection probability. However, little effort has been devoted to collaborative human and UAV search, which is necessary in many applications where the target has to be ultimately reached by human rescuers. In this paper we present a collaborative human-UAV search planning problem with the aim of minimizing the expected time at which the target is reached by human rescuers. The presented problem is of high complexity, and thus traditional exact algorithms would be very time-consuming or even impractical for solving even relatively small instances. We propose an evolutionary algorithm which uses biogeography-inspired operators to efficiently evolve a population of solutions to find the optimum or a near-optimum within an acceptable time. Computational experiments demonstrate the advantages of our algorithm over a number of other popular algorithms. The proposed method has been successfully applied to two real-world operations for searching and rescuing missing tourists in a nature reserve in China. It is estimated that, compared to the old method used by the organization, our method shortened the time required for reaching the targets by 79 minutes and 147 minutes in the two cases, respectively, providing a great improvement in the life-critical operations.

## ■ MD73

West Bldg 211B

### JFIG Panel Discussion: Tips for Writing CAREER Proposals

Sponsored: Junior Faculty JFIG

Sponsored Session

Chair: Ehsan Salari, Wichita State University, Wichita, KS, 67260, United States

Co-Chair: Anahita Khojandi, University of Tennessee, Knoxville, TN, 37996, United States

#### 1 - JFIG Panel Discussion: Tips for Writing CAREER Proposals

Ehsan Salari, Wichita State University, 120C Engineering Building, 1845 Fairmount St., Wichita, KS, 67260, United States

Recent NSF CAREER Awardees will share their experience submitting their award winning proposals, give advice and answer questions.

#### Panelists

Jennifer A. Pazour, Rensselaer Polytechnic Institute, 110 8th street, CII 5217, Troy, NY, 12180, United States

Amin Khademi, Clemson University, Central, SC, 29630, United States

Van-Anh Truong, Columbia University, 500 West 120th Street, 338 Mudd Hall, New York, NY, 10027, United States

Andy Sun, Georgia Institute of Technology, 755 Ferst Drive, Atlanta, GA, 30312, United States

## ■ MD74

West Bldg 212A

### Searching the Solution Space in Multiple Criteria Optimization

Sponsored: Multiple Criteria Decision Making

Sponsored Session

Chair: Banu Lokman, Middle East Technical University, Ankara, 06800, Turkey

Co-Chair: Murat Mustafa Koksalan, Middle East Technical University, Ankara, 06531, Turkey

#### 1 - A Multi Objective Approach to Clustering Data with Heterogeneous Inputs

Banu Lokman, Middle East Technical University, Department of Industrial Engineering, Üniversiteler Mahallesi, Ankara, 06800, Turkey, Dilay Aktas, Tulin Inkaya

Clustering algorithms mostly use a single dissimilarity matrix to partition a set of objects into a set of groups such that the objects assigned to the same group are similar for some criteria. When more than one dissimilarity matrix is available, many applications aggregate the matrices to come up with a single matrix, possibly masking the true nature of the original data. In this study, we develop a multi-objective approach to generate a number of clustering solutions considering different dissimilarity matrices.

#### 2 - Representing the Nondominated Set for Multi-objective Integer Programs

Ilgin Dogan, University of California Berkeley, Berkeley, CA, 94708, United States, Banu Lokman, Murat Mustafa Koksalan

Multi-Objective Integer Programs have a wide variety of application areas. Since the number of nondominated points grows exponentially with the problem size and finding all points is hard, generating a subset with "desired properties" is important. In this study, we observe that the distribution of nondominated points is critical in defining the desired properties of the representative subset. Based on our observations, we develop algorithms to generate a subset of points that represents the nondominated set with a prespecified coverage error. Our computational experiments show that our algorithms outperform the existing ones in terms of cardinality of the representative set and solution time.

### 3 - Robustness and Prediction Error in Multi Response Parameter Design Optimization

Melis Ozates, Middle East Technical University, Industrial Engineering Dept, Office Room 318, Ankara, 06800, Gulser Koksall, Murat Mustafa Koksall

Parameter design optimization that involves two or more responses of products or processes is a well-known research problem. This problem involves multiple objectives typically formulated as response surface models using regression. These models are constructed with some prediction error even though the model structure is appropriate. In comparing alternative solutions of the model, the decision maker (DM) has difficulty to comprehend closeness of mean response is to its target, variance of true response (robustness) and magnitude of prediction error. In this study, these components are analyzed under certain conditions and guidance is provided for the DM to facilitate the comparison.

### 4 - An Interactive Approximation Algorithm for Multi-objective Integer Programs

Banu Lokman, Middle East Technical University, Department of Industrial Engineering, Universiteler Mahallesi, Ankara, 06800, Turkey, Murat Mustafa Koksall, Pekka J. Korhonen, Jyrki Wallenius

We develop an interactive algorithm that approximates the most preferred solution for any multi-objective integer program with a desired level of accuracy. We assume that the preferences of the decision maker (DM) are consistent with a quasiconcave value function unknown to us. Based on the pairwise comparisons of the DM, we construct convex cones and eliminate the inferior regions that are close to being dominated by the cones in addition to the regions dominated by the cones. Our computational experiments show that the algorithm performs very well in terms of the quality of the solution found, the solution time, and the required preference information.

### 5 - A Multi-objective Approach for Magnetic Resonance Imaging/ultrasonography Fusion-guided Targeted Prostate Biopsies

Utku Lokman, TOBB University of Economics and Technology, Ankara, Turkey, Banu Lokman, Sukru Ali Altan, Oztug Adsan

Magnetic resonance imaging (MRI) of the prostate has recently gained substantial attention in the diagnostic workup of prostate cancer (PCa), which is the most common cancer in males. The standard prostate biopsy method is 12-core blind systematic sampling of the whole prostate. An innovative fusion of previously acquired MRI images with the real-time ultrasound (US) may lead to improved PCa detection, by identifying the suspicious areas in the prostate and targeting them accurately under MRI/US-fusion guidance, thus necessitating fewer biopsies with fewer side effects. In this study, we develop a multi-objective model to decide on the quantity of tissues obtained per each suspicious lesion.

## MD75

West Bldg 212B

### INFORMS-MAS Awards Session

Sponsored: Military and Security

Sponsored Session

Chair: Andrew Oscar Hall, United States Military Academy, West Point, NY, 10996, United States

#### 1 - MAS President Remarks

Andrew Oscar Hall, United States Military Academy, 86 B. Patridge Pl, West Point, NY, 10996, United States

The current president of MAS will provide an overview of the annual society awards, motivate future applicants, and introduce the most recent award winners who will, respectively, share an overview of their ongoing and planned work (Bonder Scholarship), present the results of their award-winning paper (Koopman Prize), and share selected insights and observations learned over a career of meaningful contributions to the discipline (J. Steinhardt Prize).

#### 2 - 2018 Seth Bonder Scholarship

The purpose of the Seth Bonder scholarship for applied operations research in military applications is to promote the development and application of process modeling and operations research analysis to military issues. The scholarship provides funding to support the development of highly qualified individuals and promote the interchange of military O.R. research knowledge in conjunction with INFORMS.

#### 3 - 2018 Koopman Prize

This award for the best published paper or report on military operations research topics directly related to the goals of MAS. The award honors the memory of Bernard Koopman (1900-1981), who was a pioneer in the field of operations research. He was active in the founding of the Operations Research Society of America (ORSA), later merged with TIMS to form INFORMS, and served as its president in 1956.

#### 4 - 2018 J. Steinhardt Prize

The J. Steinhardt Prize is sponsored by the CNA Corporation. The prize is awarded for outstanding contributions to Military Operations Research and is awarded for life work rather than for any particular contribution.

## MD76

West Bldg 212C

### MIF Paper Competition Award

Sponsored: Minority Issues

Sponsored Session

Chair: Lauren Berrings Davis, North Carolina A&T State University, Greensboro, NC, 27411, United States

Co-Chair: Sean Barnes, Univ of Maryland-College Park, College Park, MD, 20742, United States

#### 1 - A Decomposition-based Heuristic for Stochastic Emergency Routing Problems

Belleh Fontem, University of Mary Washington, Fredericksburg, VA, 22407, United States, Sharif Melouk, Burcu B. Keskin, Naeem Bajwa

This paper proposes a decomposition-based heuristic for a network delivery problem in which relief workers acquire valuable emergency supplies from relief warehouses, and transport them to meet the urgent needs of distressed population centres. The problem context dictates that the relief items reach these population centres before critical deadlines. However, coordination challenges and random disruptions introduce uncertainty in both network travel times and the destination deadlines. Hence, relief workers have to negotiate the tension between ensuring a high probability of punctual delivery and maximising the combined value of the relief supplies delivered. For an arbitrary routing scheme which guarantees punctual delivery in an uncertainty-free state of nature, the heuristic yields an upper bound on the probability that, under uncertainty, the routing scheme described will lead to tardy delivery. We demonstrate our solution approach on a small numerical example and glean insights from experiments on a realistically sized problem. Overall, our central model and proposed solution approach are useful to managers who need to evaluate routing options and devise effective operational delivery plans in humanitarian crisis situations.

#### 2 - Demand Fulfillment Probability in a Multi-item Inventory System with Limited Historical Data

Canan Gunes Corlu, Boston University, 808 Commonwealth Avenue, Boston, MA, 02215, United States, Bahar Biller, Sridhar Tayur

In a budget-constrained multi-item inventory system with independent demands, we consider the case of unknown demand parameters that are estimated from limited amounts of historical demand data. In this situation, the probability of satisfying all item demands, as a measure of demand fulfillment, is a function of the finite-sample estimates of the unknown demand parameters; thus, the demand fulfillment probability is a random variable. First, we characterize the properties of an asymptotical approximation to the mean and variance of this random variable due to the use of limited data for demand parameter estimation. Second, we use the characterization of the variance of the demand fulfillment probability for quantifying the impact of demand parameter uncertainty on demand fulfillment via numerical experiments. Third, we propose an inventory optimization problem that minimizes the variance of the demand fulfillment probability due to demand parameter uncertainty subject to a budget constraint on the total inventory investment. Our numerical experiments demonstrate that, despite the availability of limited amounts of historical demand data, it is possible to manage inventory with significantly reduced variance in the demand fulfillment probability.

#### 3 - Exploring the Value of Waiting during Labor

Karen T. Hicklin, University of North Carolina at Chapel Hill, B-24 Hanes Hall, Chapel Hill, NC, 27599-3260, United States, Julie Ivy, Fay Cobb Payton, Meera Viswanathan, Evan Myers

Of the nearly 4 million births that occur each year in the United States, almost one in every three is a cesarean delivery. Despite the increasing C-section rate over the years, there is no evidence that the increase has caused a decrease in neonatal or maternal mortality or morbidity. Bayesian decision analysis is used to model the decision between classifying a patient as "failure-to-progress, which is cause for a C-section, using either current information (prior probability) or information gathered (posterior probability) as labor continues. The Bayesian decision models determine the conditions under which it is appropriate to gather additional information (i.e., take an observation) prior to deciding to end labor and perform a C-section based on the decision maker's belief of successful labor. During an observation period, the decision maker learns more about the patient and her medical state and the likelihood of a successful vaginal delivery is updated. This study determines the conditional value of information (conditional on the decision maker's prior belief) and determines the conditions under which information has positive value. This model can be used to facilitate shared decision making for labor and delivery through communicating beliefs, risk perceptions, and the associated actions.



#### 4 - Routing and Staffing when Servers are Strategic

Ragavendran Gopalakrishnan, Cornell University, 220 Hollister Hall, Department of Civil and Environmental Engg., Ithaca, NY, 14853, United States, Sherwin Doroudi, Amy R. Ward, Adam Wierman

Traditionally, research focusing on the design of routing and staffing policies for service systems has modeled servers as having fixed (possibly heterogeneous) service rates. However, service systems are generally staffed by people. Furthermore, people respond to workload incentives; that is, how hard a person works can depend both on how much work there is, and how the work is divided between the people responsible for it. In a service system, the routing and staffing policies control such workload incentives; and so the rate servers work will be impacted by the system's routing and staffing policies. This observation has consequences when modeling service system performance, and our objective in this paper is to investigate those consequences. We do this in the context of the M/M/N queue, which is the canonical model for large service systems. First, we present a model for "strategic servers that choose their service rate in order to maximize a trade-off between an "effort cost", which captures the idea that servers exert more effort when working at a faster rate, and a "value of idleness", which assumes that servers value having idle time. Next, we characterize the symmetric Nash equilibrium service rate under any routing policy that routes based on the server idle time (such as the longest idle server first policy). We find that the system must operate in a quality-driven regime, in which servers have idle time, in order for an equilibrium to exist. The implication is that to have an equilibrium solution the staffing must have a first-order term that strictly exceeds that of the common square-root staffing policy. Then, within the class of policies that admit an equilibrium, we (asymptotically) solve the problem of minimizing the total cost, when there are linear staffing costs and linear waiting costs. Finally, we end by exploring the question of whether routing policies that are based on the service rate, instead of the server idle time, can improve system performance.

#### ■ MD77

West Bldg 213A

#### Joint Session PSOR/Practice Curated: Emergency Medical Services

Sponsored: Public Sector OR

Sponsored Session

Chair: Pieter van den Berg, RSM, RSM, Rotterdam, 3062 PA, Netherlands

#### 1 - A Scenario-based Ambulance Location Problem with Two Types of Servers

Soovin Yoon, University of Wisconsin-Madison, 1415 Engineering Drive, Room 3261, Madison, WI, 53706, United States, Laura Albert

Emergency medical service planning is challenging when there are heterogeneous patients and ambulances. Some of the challenges stem from uncertain demand and interdependencies between ambulances. We propose a data-driven approach that lifts distributional assumptions by sampling call arrival scenarios directly from the call log. A two-stage stochastic integer program is formulated to deploy and dispatch two types of servers to serve calls promptly and also match server types to varying patient needs. We conduct the numerical study with two real-world datasets to demonstrate the effectiveness of our model.

#### 2 - Determining Ambulance Destinations in the Presence of Offload Delay Using an Markov Decision Process

Mengyu Li, PhD Candidate, Dalhousie University, Halifax, NS, Canada, Peter Vanberkel

Ambulance offload delay (AOD) is a prolongation when an ambulance arrival in the emergency department (ED) and transfer of patient care, typically due to ED crowding. We formulate an infinite horizon, discrete-time Markov decision process (MDP) model to determine when it is advantageous to send appropriate patients to out of region hospitals. Out of region hospitals have longer transport times but shorter offload times. The decision model considers patient acuity, travel distance, and AOD. A computational study is applied and a policy to return ambulances to service more quickly is found. This model can be used as a decision support tool to generate optimal ambulance patient allocation policy.

#### 3 - Shift Schedule Optimization for Basic Life Support Ambulances Using Stochastic Programming

Pieter van den Berg, RSM, Burgemeester Oudlaan 50, Rotterdam, 3062 PA, Netherlands, Theresia van Essen

Many ambulance services have a fixed schedule of shifts for their vehicles. This defines the available capacity for each time of the day, which does not always match the demand for ambulances. We present a Stochastic Programming model to optimize the shift schedules of Basic Life Support (BLS) ambulances that are used for non-urgent patient transportation. By optimizing the schedule based on a large set of simulated scenarios, we find schedules that can improve the service provided to non-urgent patients. As emergency ambulances execute any patient transportation that cannot be served by a BLS ambulance, this also improves the coverage for emergency calls.

#### ■ MD78

West Bldg 213B

#### Resilient Infrastructure and Community Networks

Sponsored: Public Sector OR

Sponsored Session

Chair: Kash Barker, University of Oklahoma, OK, 73019, United States

#### 1 - Social-vulnerability Driven Infrastructure Network Component Importance Measures

Deniz Berfin Karakoc, University of Oklahoma, 202 W. Boyd, Room 448, Carson Engineering Center, Norman, OK, 73019, United States

Critical infrastructures are often described as interdependent in nature, vulnerable to multiple hazards, and vital for societies. To plan a comprehensive preparedness plan, we identify the critical components that have the largest impact on the performance of these networks and on the society. In this work, we propose two different component importance measures to quantify the effect of disruption and the impact of restoration on components over the resilience of interdependent infrastructure networks. We integrate multiple social vulnerability measures using a multi-criteria decision analysis technique and illustrate our approach with three infrastructure networks in Shelby County, TN.

#### 2 - Restoring Community Structures in Interdependent Infrastructure Networks

Kash Barker, University of Oklahoma, 202 West Boyd, Room 124, Norman, OK, 73019, United States, Yasser A. Almoghathawi

Community structures exist in many infrastructure networks where each network is partitioned into sets of densely connected components with sparse connections between them. However, infrastructure networks depend on one another for their proper functionality, which potentially make them highly vulnerable to disruptions. This work studies the restoration problem of community structures in interdependent infrastructure networks following a disruption. A restoration model is proposed with the objective of enhancing the resilience of the system of interdependent networks considering their interdependencies. The proposed model is illustrated through a set of interdependent networks.

#### 3 - Measuring Multi-dimensional Network Resilience

Christopher Zobel, Virginia Tech, 880 West Campus Drive, Blacksburg, VA, 24061-0235, United States, Milad Baghersad

This paper discusses a new multi-dimensional measure of critical infrastructure network resilience that takes the relative resilience of different network components into account. The new measure allows for explicitly considering the tradeoffs between system loss and recovery time, and it also allows for applying relative weights to different sub-components in order to represent varying degrees of criticality within the network.

#### 4 - Infrastructure Resilience Evaluation in Multiple Public Transportation Systems when Disruptions Occur, the Case of New York City

Gabriela Noemi Gongora Svartzman, Stevens Institute of Technology, 1 Castle Point On Hudson, Hoboken, NJ, 07030, United States, Jose Emmanuel Ramirez-Marquez, Kash Barker

Public transportation systems can be subject to unforeseen events, ranging from sick passengers up to weather conditions. The novelty of this research resides in evaluating the resilience of public transportation as multi-modal, interdependent systems. The usual behavior of different modes of transportation (buses, subway, bicycles) is modeled through discrete events simulations, and compared against their real data when a range of disruptions occur. The aggregated commuting times, the type of area affected (e.g. residential or commercial) and the possible transportation alternatives are calculated. Visualizations are created to analyze New York City as a case study.

#### 5 - Stochastic Optimization for Maintenance Decisions in Transportation Networks under Seismic Hazard

Jorge-Mario Lozano, Universidad de los Andes, Bogota, 111711, Colombia, Camilo Gómez, Jack W. Baker

Transportation networks are particularly vulnerable to seismic hazards and critical for cities' sustainability. Hence, deciding whether to retrofit a bridge in the present, or wait to repair it after an earthquake, is important to ensure reasonable travel times and limit the disruption of city dynamics. In this paper, we present a risk management optimization approach for the San Francisco Bay Area for a hazard-consistent set of earthquake scenarios. We use a regularized continuous Benders decomposition strategy, which provides advantages with respect to existing combinatorial approaches in terms of convergence, as well as shadow price analysis and prioritization capabilities.

**Tuesday, 7:30AM - 9:00AM****■ TA01**

North Bldg 121A

**Data-Driven and Robust Optimization I**

Sponsored: Optimization/Optimization Under Uncertainty

Sponsored Session

Chair: Phebe Vayanos, University of Southern California, Los Angeles, CA, 90089, United States

**1 - Distributionally Robust Strategic Queues**

Madhushini Narayana Prasad, The University of Texas at Austin, Austin, TX, 78712, United States, Grani Adiwena Hanasusanto, John Hasenbein

We extend the classical Naor's model for observable systems by relaxing the principal assumption of a deterministic arrival rate. While the Markovian assumptions still hold, we assume the arrival rate is uncertain and only the information about first-order moment is known to the strategic customers and managers. We derive the optimal threshold strategies of a revenue maximizer, a social optimizer and an individual customer, by maximizing the worst-case expected profit over the set of distributions satisfying the known information. We then compare and contrast our observations with the classical model results, and finally present our computational results.

**2 - Robust Factored Markov Decision Process**

Man-Chung Yue, Imperial College London, London, United Kingdom

Factored Markov decision process where the transition probabilities are uncertain is considered. We first provide a mathematical framework and discuss the difficulties of this class of problems. In particular, the optimization problem associated with the value function of any given policy has exponentially many constraints and variables and suffers from multi-linearity. Based on a novel rectangularity assumption, we construct a lifted MDP whose value function is the equivalent to that of the original factored MDP but do not suffer from multi-linearity. Efficient approximation is then obtained by combining this result with techniques such as linear approximation to reduce the exponentiality.

**3 - Data-driven Approach for Demand Forecasting and Inventory Control of Slow-moving Items**

Sheng Bi, National University of Singapore, Singapore, 138600, Singapore, Long He, Chung-Piaw Teo

We consider the demand forecasting and inventory control problem with intermittent usage. The data is often used to estimate the demand distribution if the item is ordered, and also the probability that an order will materialize in a period. However, errors in the estimation may skew the performance of this approach. In this paper, we use a portfolio approach to hedge the risk of inventory exposure between successive order arrivals, using as input an estimate of the joint distribution of demand and interarrival time. To account for errors in estimation, we propose a distributionally robust model using the Wasserstein uncertainty set to determine the state-dependent order-up-to levels.

**4 - Robust Reinforcement Learning**

Huan Xu, ISyE Ga Tech, 755 Ferst Drive, NW., Atlanta, GA, 30332, United States, Aurko Roy, Sebastian Pokutta

We study reinforcement learning under model misspecification, where we do not have access to the true environment but only to a reasonably close approximation to it. We address this problem by extending the framework of robust MDPs to the model-free Reinforcement Learning setting, where we do not have access to the model parameters, but can only sample states from it. We define robust versions of Q-learning, SARSA, and TD-learning and prove convergence to an approximately optimal robust policy and approximate value function respectively. We scale up the robust algorithms to large MDPs via function approximation and prove convergence under two different settings.

**■ TA02**

North Bldg 121B

**Robust Optimization – Dynamic and Discrete Considerations**

Sponsored: Optimization/Optimization Under Uncertainty

Sponsored Session

Chair: Dan Andrei Iancu, Stanford University, Stanford, CA, 94107, United States

**1 - Distributionally Robust Linear and Discrete Optimization with Marginals**

Peng Xiong, National University of Singapore, Singapore, Singapore, Zhi Chen, Melvyn Sim

We study linear and discrete optimization problems in which the objective coefficients are chosen randomly from a distribution, and the goal is to find robust bounds on the expected optimal value and the marginal distribution of the optimal solution. The set of joint distributions is assumed to be specified up to only the marginal distributions. With a primal-dual formulation, we generalize previous assumptions on the marginals to arbitrary marginals using optimal transport theory, and we identify a sufficient condition for polynomial time solvability using extended formulations. We conclude by exploring the implications on the solvability of problems in areas such as scheduling and max-flow.

**2 - Adaptive Robust Optimization with AROMA**

Peng Xiong, National University of Singapore, Singapore, Singapore, Zhi Chen, Melvyn Sim

We present a tractable framework for adaptive robust optimization. The proposed framework could naturally unify classical stochastic programming, robust optimization, and more recent distributionally robust approaches with a new scenario-wise ambiguity set. Such an ambiguity set inspires a scenario-wise recourse approximation that provides tractable solutions to adaptive problems. Based on the new framework, we have developed a generic software package, named AROMA (Adaptive Robust Optimization Made Accessible) for a straightforward implementation of the proposed framework. Experiments are conducted to demonstrate the effectiveness of the proposed framework and software package.

**3 - Dynamic Robust Optimization and Discrete Convexity**

Dan Andrei Iancu, Stanford University, 655 Knight Way, Stanford, CA, 94107, United States, Yehua Wei

We discuss necessary and sufficient conditions for the optimality of specific classes of policies in dynamic robust optimization. We then focus on the specific case of affine policies, and show how our conditions can be used to recover and generalize several existing results in the literature. Our treatment draws interesting connections with the theory of discrete convexity (L-natural / M-natural convexity and multimodularity) and global concave envelopes, which may be of independent interest. Time permitting, we also discuss some related applications of the results in the context of a learning and stopping problem.

**4 - Robust Dynamic Optimization for R&D Project Selection**

Aurelie Thiele, Southern Methodist University

We investigate adaptive decision rules in multi-stage binary programming in the context of R&D project selection, where a manager can decide whether to continue or abandon projects, subject to future cash flow uncertainty represented using a robust optimization paradigm. The manager can choose from projects with various risk-return profiles. Information about cash flow uncertainty is updated over time. We study the computational tractability of the approach and present theoretical insights. Numerical experiments are encouraging.

**■ TA03**

North Bldg 121C

**Managing Innovation I**

Sponsored: Technology, Innovation Management &amp; Entrepreneurship

Sponsored Session

Chair: Wenli Xiao, University of San Diego, San Diego, CA, 92110, United States

**1 - The Impact of Social Orientation on Firm Innovation**

Xiaojin Liu, University of Virginia, Darden, Charlottesville, VA, 22903, United States, Raul Chao

This study addresses the questions of whether and how firm social orientation influences firm innovation. In so doing, we propose mechanisms geared toward either proactive or reactive social orientation in project funding. Integrating large scale archival datasets, we empirically investigate the long term impact of social orientation on firm innovation.

## 2 - The Impact of Knowledge Transfer on Knowledge Development Strategies

Wenli Xiao, University of San Diego, 5998 Alcala Park, Olin Hall 335, San Diego, CA, 92110, United States, Cheryl Gaimon

We introduce a dynamic model to explore a manager's pursuit of a new product development project and an existing product improvement project. Two key features of our model are the characterization of the knowledge transfer process from the new product development project to the existing product improvement project, and the absorptive capacity for both knowledge development and knowledge transfer. We provide the optimal strategies for knowledge development and knowledge transfer for the two projects.

## 3 - Search for the Best Alternative: An Experimental Approach

Gulru Ozkan-Seely, University of Washington, Seattle, WA, United States, David C. Hall, Jeremy Hutchison-Krupat

We use a controlled experiment to study how this behavior is impacted by two factors: the difficulty associated with an initiative, and the degree to which its value is sensitive to time. Our results indicate that, individuals who face a more difficult initiative under-invest to a greater extent than those who face a simpler initiative.

## 4 - Blockchain and the Value of Operational Transparency for Supply-Chain Finance

Gerry Tsoukalas, Wharton School of Business, 3730 Walnut Street, 567 Jon M. Huntsman Hall, Philadelphia, PA, 19104, United States, Jiri Chod, Nikolaos Trichakis, Henry Aspegren, Mark Weber

We examine how blockchains, which were originally designed to provide verifiability of digital goods transactions, can provide verifiability of physical goods transactions. We identify some of the unique implementation challenges and propose ways to mitigate them. To exemplify, we describe an open-source blockchain platform we developed and one of its use cases in agricultural supply chains. We then develop a theory showing how the proposed blockchain-enabled verifiability of physical goods transactions can be leveraged by high-quality firms to signal their operational capabilities through their upstream inventory orders, and thereby finance their operations more efficiently.

## ■ TA04

North Bldg 122A

### Joint Session OPT/Practice Curated: Mixed-Integer Quadratic Programming

Sponsored: Optimization/Integer and Discrete Optimization  
Sponsored Session

Chair: Richard Forrester, Dickinson College, Department of Mathematics, College and Louthier Street, Carlisle, PA, 17013, United States

#### 1 - Representability in Mixed-Integer Quadratic Programming

Jeffrey Poskin, Boeing, Seattle, WA, United States, Alberto Del Pia

Representability results play a fundamental role in optimization since they provide characterizations of the feasible sets that arise from optimization problems. In this work we study the sets that appear in the feasibility version of Mixed-Integer Quadratic Programming (MIQP) problems. MIQP has a number of practical applications, including in power systems and portfolio optimization, and also serves as a first generalization of Mixed-Integer Linear Programming to Mixed-Integer Nonlinear Programming. This work continues the study of representability in Mixed-Integer Nonlinear Programming performed by the authors as well as Lubin, Zadik, and Vielma. We provide a number of complete characterizations of the sets that appear in different classes of convex MIQPs. These settings include (i) bounded convex MIQPs, (ii) continuous convex QPs, and (iii) mixed binary convex quadratic optimization problems.

#### 2 - Efficient Ways of Computing Strong Upper and Lower Bounds for Generalized Quadratic Assignment Problems

Monique Guignard-Spielberg, Professor, University of Pennsylvania, 500 JMH-Old Department, Wharton School/Univ Penn, Philadelphia, PA, 19104-6340, United States, Aykut Ahlatcioglu, Jongwoo Park

The Generalized Quadratic Assignment Problem (GQAP) assigns a job to one machine but a machine can handle several jobs, within its capacity. Assignment costs depend on pairwise combinations of assignments. We describe the Convex Hull Heuristic and use it to generate quickly good feasible solutions. We also show how to compute RL2-quality bounds by computing Lagrangean bounds for a special 0-1 RL1-like model. We present results for GQAP instances from the literature as well as for the special case of the Crossdock Door Assignment Problem with up to 6000 0-1 variables.

## 3 - Optimal Solutions to the Quadratic Knapsack Problems: Experiments with Improved Linearization

Yu Du, Professor, University of Colorado Denver, 1475 Lawrence Street, Office 5021, Denver, CO, 80202-2219, United States, Gary A. Kochenberger, Fred W. Glover, Haibo Wang

A common approach for finding optimal solutions to Quadratic Knapsack Problems (QKP) is to adopt an equivalent linearization of the quadratic model and then solve the linear model with an exact solver such as CPLEX. Previous studies have demonstrated the potential of this approach. At the same time, these studies have exposed a limitation in terms of long solution times as problems scale in size. In this study we adopt a successful linearization and experiment with simple ways to enhance its performance by strengthening a key parameter (bound) in the model. Substantial computational experience is provided giving guidance for improved practice.

## 4 - A Computational Study of Linearization Strategies for 0-1 Quadratic Programs

Richard Forrester, Professor of Mathematics, Dickinson College, Department of Mathematics, College and Louthier Street, Carlisle, PA, 17013, United States

A common approach for solving 0-1 quadratic programs is to recast the nonlinear program into an equivalent form through the introduction of auxiliary variables and constraints. Then the resulting model can be solved using a standard mixed 0-1 solver. In this talk we present the results of an extensive computational study examining the strengths and weaknesses of the many different linearization approaches considered in the literature. In addition, we provide recommendations for which approach to use based on the specific class of 0-1 quadratic programs to be optimized.

## ■ TA05

North Bldg 122B

### Recent Advances in Optimization Algorithms

Sponsored: Optimization/Linear and Conic Optimization  
Sponsored Session

Chair: Robert Michael Freund, Massachusetts Institute of Technology, 77 Massachusetts Avenue E62-567, E62-567, Cambridge, MA, 02139-4307, United States

#### 1 - Accelerating Greedy Coordinate Descent Methods

Robert Michael Freund, Professor, Massachusetts Institute of Technology, 77 Massachusetts Avenue E62-567, E62-567, Cambridge, MA, 02139-4307, United States, Haihao Lu, Vahab Mirrokni

We study ways to accelerate greedy coordinate descent in theory, in practice, or both. We introduce and study two algorithms: Accelerated Semi-Greedy Coordinate Descent (ASCD) and Accelerated Greedy Coordinate Descent (AGCD). While ASCD takes greedy steps in the x-updates and randomized steps in the z-updates, AGCD only takes greedy steps (but lacks acceleration guarantees). We show that ASCD achieves  $O(1/k^2)$  convergence. Our computational experiments demonstrate that AGCD and ASCD outperform Accelerated Randomized Coordinate Descent on a wide variety of instances. We also present a Lyapunov energy function argument that yields insight into the different performance of these methods.

#### 2 - Solving Linear Inequalities via Non-convex Optimization

Jourdain Lamperski, MIT, Cambridge, MA, 02139, United States

We mainly consider solving homogeneous linear inequalities. We formulate a non-convex optimization problem in a slightly lifted space, whose critical points map to feasible solutions of the linear inequalities. We show various properties of the non-convex objective function and develop an algorithm that computes critical points thereof, thus yielding an algorithm for linear inequalities. We establish convergence guarantees for the algorithm and further investigate its performance via computational experiments.

#### 3 - An Optimal Algorithm for Stochastic Three Composite Optimization

Renbo Zhao, MIT, Muckley Bldg, 1 Amherst St, Cambridge, MA, Boston, MA, 02142, United States

We develop an optimal primal-dual first-order algorithm for a class of stochastic three-composite convex minimization problems. The convergence rate of our method not only improves upon the existing methods, but also matches a lower bound derived for all first-order methods that solve this problem. We extend our proposed algorithm to solve a composite stochastic program with any finite number of nonsmooth functions. In addition, we generalize an optimal stochastic alternating direction method of multipliers algorithm proposed for the two-composite case to solve this problem, and establish its connection to our optimal primal-dual algorithm.



#### 4 - Convergence Rate of Distributed Random Projections

Thinh Doan Doan, Georgia Institute of Technology,  
755 Ferst Drive, Atlanta, GA, 30332, United States

Stochastic gradient descent is a common algorithm used in machine learning, especially when the loss function is in a separable form. Here, we consider SGD for constrained convex optimization problems, where the constraint is expressed as an intersection of a large number of convex sets. We study a distributed version of the random projections since a centralized approach is too slow for very large-scale problems. Under a mild regularity condition on the convex sets, we show that the rate of convergence of distributed SGD with distributed random projections is the same as that of distributed SGD applied to a problem with no constraints, except for a factor which captures the regularity assumption.

#### 5 - Motivation Dynamics: A Nonlinear Saddle Point Algorithm for Dynamically Satisfying Statically Unsatisfiable Constraints

Paul Reverdy, Assistant Professor, University of Arizona,  
1130 N. Mountain Ave., P.O. Box 210119, Tucson, AZ, 85721,  
United States

We propose a dynamical system that can be interpreted as a saddle-point algorithm with a nonlinear Lagrange multiplier dynamics. The system is designed to solve constraint satisfaction problems in Euclidean space. When the constraints are reconcilable, i.e., when there exists a feasible solution, the system converges to the feasible solution. When no such solution exists, we derive conditions under which the system exhibits a stable limit cycle where it periodically satisfies the various constraints.

### ■ TA06

North Bldg 122C

#### Advances in MINLP

Sponsored: Optimization/Global Optimization

Sponsored Session

Chair: Jean-Philippe P. Richard, University of Florida, Gainesville, FL,  
32611-6595, United States

#### 1 - Stronger Polyhedral Relaxations for Polynomial Optimization Problems

Aida Khajavirad, Carnegie Mellon University, 1405 Second Ave,  
Apartment 3S, New York, NY, 10021, United States,  
Alberto Del pia

We consider the Multilinear set defined by a collection of multilinear terms over the unit hypercube. Such sets appear in factorable reformulations of many types of MINLPs. Utilizing an equivalent hypergraph representation for the Multilinear set, we derive various types of facet defining inequalities for its polyhedral convex hull and present a number of tightness results based on the acyclicity degree of the underlying hypergraph. Subsequently, we detail on the complexity of corresponding separation problems and embed the proposed cut generation algorithm at every node of the branch-and-reduce global solver BARON. Extensive computational results will be presented.

#### 2 - Improved Representations of the Quadratic Linear Ordering Problems

Boshi Yang, Clemson University, Clemson, SC, United States,  
Audrey Nicole DeVries, Warren P. Adams

The quadratic linear ordering problem (QLOP) seeks a least-cost permutation of  $n$  objects where a cost is incurred based on the relative ordering and on products of pairwise orderings. We obtain three results for the QLOP. First, we provide a lifting theorem about the facets of QLOP. Second, we obtain the convex hull representation for  $n=3$  objects with only half the number of restrictions as recent work. Third, we provide the convex hull representation for  $n=4$  objects, expressed in terms of five families of facets. Computational results are presented to show the advantage of our reduced number of constraints in a solution strategy.

#### 3 - Computational Experimentation with Branching Strategies for Global Optimization of Nonlinear Programs and Mixed Integer Nonlinear Programs

Carlos Jose Nohra Khouri, Carnegie Mellon University,  
Department of Chemical Engineering, 5000 Forbes Avenue,  
Pittsburgh, PA, 15213, United States, Nikolaos Sahinidis

Current global optimization solvers rely predominantly on branch-and-bound algorithms for the solution of nonconvex nonlinear programs (NLPs) and mixed-integer nonlinear programs (MINLPs). The efficiency of these algorithms depends to a large extent on the techniques used for partitioning the search space. In this work, we investigate novel branching strategies for nonconvex NLPs and MINLPs. We integrate these strategies into the global optimization solver BARON and analyze their impact by conducting an extensive computational study on a large collection of problems selected from publicly available test sets.

#### 4 - Computational Evaluation of New Models for Tree Ensembles Optimization

Jean-Philippe P. Richard, University of Minnesota, Industrial and  
Systems Engineering, 111 Church Street S.E., Minneapolis, MN,  
55455, United States, Jongeun Kim, Bijan Taslimi,  
Mohit Tawarmalani

Tree ensemble models are widely used to predict the value of a dependent variable as a function of independent variables. When the independent variables are controllable, the problem of optimizing the value of the dependent variable by adjusting the values of the independent variables naturally arises. Models have recently been proposed for such three ensembles optimization problems. In this talk, we introduce new models, formulations and heuristics for this problem and compare provide a numerical evaluation of their performance.

### ■ TA07

North Bldg 123

#### Supply Chain and Transportation Networks

Sponsored: Optimization/Network Optimization

Sponsored Session

Chair: Pedro Cesar Lopes Gerum, Rutgers University, 100 Canterbury  
Court, Piscataway, NJ, 08854, United States

#### 1 - Optimizing Medical Supply Distribution in Rural Regions Considering Uncertainty

Larissa P. G. Petroianu, PhD Student, University of Washington,  
1703 Harvard Avenue, apartment 6, Seattle, WA, 98122,  
United States, Zeldia B. Zabinsky, Mauricio G. C. Resende

Delivery of medical supplies to rural regions is a challenge. Uncertainty contributes to making this a complex task. In the rainy season, roads are often flooded and other means of transportation are needed. We seek to improve the efficiency of distribution, considering the cost of transportation, uncertainties of demand and weather, transportation modes, and transit times. We construct four models: deterministic, robust, chance constraint, and two-stage stochastic program. We present numerical results and discuss differences between the models and how each one addresses uncertainty.

#### 2 - A Comparative Study of Supply Network Robustness: Topological Sensitivity Analysis for Random and Targeted Disruptions

Hyunwoo Park, The Ohio State University, 2100 Neil Ave, 632  
Fisher Hall, Columbus, OH, 43210, United States, Yusoon Kim

Based on 38 empirically derived models of supply networks representing multiple real-world industries, we conducted a sensitivity analysis of supply network robustness. We propose a new measure of supply network robustness to disruption when there are multiple sources and multiple sinks in a network. In the analysis, we simulate both random and targeted disruptions and explain varying vulnerabilities across different supply networks based on the topology (i.e., underlying network structure) and stage-level operational attributes such as cost and time.

#### 3 - The European Hinterland Transport Network as a Complex Network - How is Robustness Affected by the Multi-mode Structure?

Camill Harter, PhD Candidate, Erasmus University Rotterdam,  
Burgemeester Oudlaan 50, T09-08, Rotterdam, 3062PA,  
Netherlands, Rob A. Zuidwijk, Otto Koppius

Robustness of transport networks has widely been studied for unimodal networks. Hinterland container transport, however, comprises multiple interlinked networks formed by different transport modes, which impacts robustness. On the one hand, alternative transport modes provide backup capacities, on the other hand, disruption can cascade easier across interlinked networks. We show that robustness against random and targeted failure differs substantially between multimodal networks and their unimodal counterparts and assess how this generalizes to other multimodal networks. We use a unique dataset containing all intermodal services scheduled in the European hinterland from 2016-2018.

#### 4 - Describing the Distribution of Traffic Density on Corridors Affected by Non-recurrent Congestion Using Minimal Statistical Information

Pedro Cesar Lopes Gerum, Rutgers University,  
173 Walnut Court, Highland Park, NJ, 08904-1931, United States,  
Melike Baykal-Gursoy, Marcelo Ricardo Figueroa

We investigate reliability measures to assess the performance of roadway traffic density subject to non-recurrent incidents through applied queueing theory. For this, we consider stationary analytical solutions for the number of customers with Markov-modulated service rates. We validate these parametric distributions for peak and non-peak hours, and then generate explicit dependencies on traffic density and incident parameters, thus avoiding the use of costly simulation. Our model will contribute to the design of management tools for roadway traffic, and to incident mitigation, leading to safer and more efficient movement of people and goods.

## ■ TA08

North Bldg 124A

**Network Optimization and Graph Algorithms II**

Sponsored: Optimization/Network Optimization

Sponsored Session

Chair: Gino J. Lim, University of Houston, Professor and Chairman,  
Dept of Industrial Engineering, Houston, TX, 77204, United States

**1 - Generating Directed Networks with Predefined Degree Distribution and Directed Clustering Coefficient**

Alex Marshall, Analyst, The Perduco Group, Beavercreek, OH,  
45431, United States, Paul F. Auclair

Experimental designs that require the generation of directed networks with predefined clustering are often limited to the undirected clustering coefficient. This presentation reviews an adaption and extension of the Kashyap-Ambika Degree Preserving Rewiring (DPR) techniques for tuning clustering in directed networks. The adaptation enhances the DPR techniques by facilitating downward, in addition to upward, adjustment of directed clustering. The extension integrates the DPR techniques and adaptations enabling the systematic generation of directed networks with a predefined degree distribution and directed clustering coefficient.

**2 - A Bi-objective Covering Tour Problem**

Sanaz Goldani, PhD Student, North Carolina State University,  
Raleigh, NC, 27606, United States, Yahya Fathi

We introduce several families of valid inequalities for the constrained Covering Tour Problem and discuss appropriate strategies for incorporating these inequalities in the context of a branch and cut algorithm for solving the corresponding IP model. We then employ this algorithm to solve a corresponding bi-objective covering tour problem and present the result of a limited computational study.

**3 - The Team-orienting Problem with Diversity Constraints: Application to the Travel Industry**

Yanlu Zhao, ESSEC Business School, Paris, France,  
Laruent Alfordari

This paper examines how the online travel agencies (OTAs) are re-structuring human modern lifestyle. We formulate the tour plan process as a team orienting problem (TOP) with restriction on budget and duration. Different from the TOP, we are the first to consider the diversity in tour design and provide a diversified tour package rather than multiple independent tours. Such diversity enables us to explore the tradeoff between personal preferences in customer choices and economies of scale in agency bargain power. Further, we reformulate the model as a tractable master problem and solve it by column generation. Finally, we use a real dataset to test the algorithm and explore the effect of diversity.

**4 - An Integrated Problem of Hub Location and Revenue Management with Network Disruptions**

Yanting HOU, Tongji University, 1500 Siping Road, Shanghai,  
200092, China

We maximize the total profits in an integrated problem of star capacitated single allocation p-hub location problem and revenue management taking into account disruptions and customer segmentation considerations. The problem is to decide on the locations of hubs and their capacities at the risk of disruptions, the connections, the booking limits and the protection levels of tickets on multiple fare classes.

**5 - A Consistent Network Complexity Measure and its Application in Logistics Network Design**

Yunhui Lin, National University of Singapore, Engineering Drive 2,  
Blk E1 #07-21, Singapore, Singapore, Yuan Wang, Loo Hay Lee

The problem to quantify network complexity has been a challenging topic in various disciplines. Most of the network complexity measures are not consistent and some of them are even counter-intuitive. We examine the consistency of some entropy-based network complexity measures for directed graph, and check whether these measures agree with our intuition. We finally propose a consistent network complexity measure and show how to apply it as a decision making tool and how to integrate into optimization models in logistics network designs.

**6 - A Bi-objective Optimization Model Toward a Robust Network Partitioning**

Gino J. Lim, University of Houston, Professor and Chairman, Dept  
of Industrial Engineering, Houston, TX, 77204, United States,  
Saeedeh Abbasi, Masoud Barati

Dealing with large network-structured systems is difficult. Therefore, a parallel processing is recommended by partitioning the network; which can facilitate the process by reducing the size of the target network at each moment. The common partitioning criterion is modularity while considering another metric beside is beneficial to the result. This study addresses the network partitioning challenges in vulnerability of the partitions via maximization of edge-connectivity beside the modularity. The problem is formulated as a bi-objective maximization model. Two case studies of random graphs in size of 6- and 40-node are analyzed to demonstrate the model's performance.

## ■ TA09

North Bldg 124B

**Nonconvex and Stochastic Optimization**

Sponsored: Optimization/Nonlinear Programming

Sponsored Session

Chair: Mert Gurbuzbalaban, Massachusetts Institute of Technology,  
Cambridge, MA, 02139, United States

Co-Chair: Nuri Denizcan Vanli, Massachusetts Institute of Technology,  
Cambridge, MA, 02141, United States

**1 - Beyond Gradient Methods: Models in Stochastic and Non-convex Optimization**

John Duchi, Department of Statistics - 390 Serra Mall,  
Stanford University, Stanford, CA, 94305, United States

We consider minimization of stochastic functionals that are (potentially) non-smooth and non-convex, but are locally approximable (in a sense we make precise) by convex functions. This class includes compositions of a (potentially) non-smooth convex function  $h$  and smooth function  $c$ . We develop methods that build local models of the problem and show theoretically and empirically that they have good performance, typically substantially better than subgradient methods. We analyze this problem class in the context of generic nonlinear measurement problems, showing that we can solve these problems (even with faulty measurements) with high probability under appropriate measurement models.

**2 - Implicit Bias of Optimization in Learning**

Suriya Gunasekar, Toyota Technological Institute at Chicago,  
Chicago, IL, United States, Jason Lee, Nathan Srebro,  
Daniel Soudry

In optimization problems with multiple non-equivalent global minima, we look at the question of how different optimization algorithms influence the specific global minimum they converge to? We will focus on underdetermined regression or separable classification tasks in machine learning, where the training loss has multiple global minima that all give zero training loss, but different minima have different performance on test data. In such problems we will see cases where the specific global minimum reached by specific optimization algorithms have simple characterizations in terms of the geometry of the algorithm and independent of hyperparameter choices such as step size and momentum.

**3 - Robust Accelerated Gradient Method**

Alireza Fallah, Massachusetts Institute of Technology, 77  
Massachusetts Ave., Room 32-D640, Cambridge, MA, 02139,  
United States, Mert Gurbuzbalaban, Asuman Ozdaglar,  
Necdet Serhat Aybat

We study the trade-off between rate of convergence and robustness to gradient errors in designing the first-order algorithms. In particular, we focus on standard optimization algorithms such as gradient descent (GD) and Nesterov's accelerated gradient (AG) method for strongly convex objectives when the gradient has random errors in the form of additive white noise. In this work, we develop a tractable algorithm that allows us to set the parameters of each algorithm to achieve a particular trade-off between rate and robustness. In addition, our results show that AG can achieve acceleration while being more robust to random gradient errors.

**4 - Spurious Local Minima in Neural Networks: A Critical View**

Chulhee Yun, Massachusetts Institute of Technology, Cambridge,  
MA, United States, Suvrit Sra, Ali Jadbabaie

We investigate the loss surface of nonlinear neural networks. We prove that even for networks with one hidden layer and "slightest" nonlinearity, there can be spurious local minima. Our results thus indicate that in general "no spurious local minima" is a property limited to deep linear networks. Specifically, for ReLU(-like) networks we prove that for almost all practical datasets there exist infinitely many local minima. We also present a counterexample for more general activation functions, for which there exists a local minimum strictly inferior to the global minimum. Our results make the least restrictive assumptions relative to the existing results on local optimality in neural networks.

**5 - A Stochastic Trust Region Algorithm with Careful Step Normalization**

Rui Shi, Lehigh University, Lehigh University, Bethlehem, PA,  
United States, Benjamin Field Hobbs

In this talk, we are going to present a stochastic trust region algorithm with emphasis on the normalized steps. We derive the method from a stochastic trust region subproblem but we will also show that if we adapt the trust region subproblem directly, we are going to lose the convergence. Hence our approach involves a modified update scheme which we show convergence for both convex and nonconvex objectives. We will also provide numerical example to show that our method outperform SG in convex and nonconvex machine learning problems.

## ■ TA10

North Bldg 125A

### Joint Session MSOM/Practice Curated: Marketplace Innovation

Sponsored: Manufacturing & Service Oper Mgmt  
Sponsored Session

Chair: Fuqiang Zhang, Washington University in St. Louis, St. Louis, MO, 63130, United States

#### 1 - Managing Ride-sharing Demand Shocks with Surge Pricing

Bin Hu, UNC Chapel Hill, UNC Chapel Hill, Assistant Professor, Chapel Hill, NC, 27599, United States, Ming Hu, Han ZHU

Surge pricing by ride-sharing platforms has long been accused by media of gouging riders. Instead, economic theory advocates surge pricing as a way of efficiently regulating supply and demand. We propose an alternative argument in support of surge pricing. An important, but often neglected feature is that drivers react magnitudes slower than riders to surge pricing. A short-lived surge can inform nearby drivers of unserved riders, attracting them to relocate and leading to a more efficient market outcome than maintaining less varied prices. Moreover, we find a low-then-high penetration surge may be more profitable for the platform than a more commonly-used high-then-low skimming surge.

#### 2 - Crowdfunding or Bank Financing: Effects of Market Uncertainty and Word-of-mouth Communication

Fasheng Xu, Washington University in St. Louis, Saint Louis, MO, 63130, United States, Xiaomeng Guo, Guang Xiao, Fuqiang Zhang

In the fast growing rewards-based crowdfunding marketplace, startups launch projects not only to raise funding directly from the crowd to cover early stage investment, but also to expand product awareness via word-of-mouth communication. Compared to bank financing, we find that crowdfunding is always preferred by startups under weak product awareness base or poor credit rating; otherwise, crowdfunding may underperform when market uncertainty is within certain medium range. Our model provides a framework to rationalize the advantage of crowdfunding by demonstrating three underlying benefits: capital-raising, awareness-expanding, and demand-validating.

#### 3 - Social Learning and the Design of New Experience Goods

Yiangos Papanastasiou, University of California at Berkeley, Pnina Feldman, Ella Segev

This work focuses on the implications of social learning from product reviews for a monopolist firm's choice of product design. Our main finding is that, in the presence of social learning, the firm's design choice results in a product whose expected quality is lower either in the absolute sense, or relative to the product's price.

#### 4 - Information Sharing on Retail Platforms

Zekun Liu, Washington University in St. Louis, One Brookings Drive, St. Louis, MO, 63130, United States, Fuqiang Zhang, Dennis Zhang

We study how the retail platform should share demand information with its sellers under revenue sharing contract. With no fairness concern, the platform always truthfully shares market or private information to a subgroup of the sellers. With fairness concern, the platform has to offer symmetric information for each seller. When the number of sellers is relatively big, the platform has the incentive to share noised private signals to sellers. Furthermore, when the sellers are heterogeneous in their market power, we show that the platform prefers to share information truthfully with sellers who have relatively low market power.

## ■ TA11

North Bldg 125B

### MSOM iFORM Sessiona

Sponsored: Manufacturing & Service Oper Mgmt/iFORM  
Sponsored Session

Chair: Robert Louis Bray, Kellogg School of Management, Northwestern University, Evanston, IL, 60202, United States

Co-Chair: Juan Camilo Serpa, McGill University, Montreal, QC, H2L 3S2, Canada

#### 1 - A Structural Estimation Approach to Agent Attrition

Seyed Morteza Emadi, University of North Carolina at Chapel Hill, 300 Kenan Center Drive, Chapel Hill, NC, 27599, United States, Bradley R. Staats

Worker attrition is a costly and operationally disruptive challenge throughout the world. Although large bodies of research have documented drivers of attrition and its operational consequences, managers still lack an integrated approach to understanding attrition and making decisions to address it on a forward-going basis. To fill this need, we build a structural model that captures both the firm's

decision to terminate a workers' employment (involuntary attrition) and uses an optimal stopping problem process to model a workers' decision to leave the firm (voluntary attrition).

#### 2 - Loss Aversion in Managers' Pricing Decision Making at a Fast Fashion Retailer

Anna Saez de Tejada Cuenca, UCLA Anderson School of Management, 110 Westwood Plaza, B-501, Los Angeles, CA, 90024, United States, Felipe Caro, M. Keith Chen

We analyze managers' pricing decision making during the sales season of a fast fashion retailer. We observe empirically that, even when assisted by a DSS that recommends revenue-maximizing prices, they systematically deviate from the optimal prices, in a way that is compatible with a number of behavioral biases: loss aversion, salience of the inventory, time discounting, and status quo. We build a structural model to disentangle their degree of loss aversion from other biases, and compare loss aversion coefficients across managers and across product groups (e.g., fashion vs. basics).

#### 3 - Ration Gaming and the Bullwhip Effect

Robert Louis Bray, Kellogg School of Management, Northwestern University, 830 Hinman Ave., 2s, Evanston, IL, 60202, United States

We model a single-supplier, 73-store supply chain as a dynamic discrete choice problem. We estimate the model with transaction-level data, spanning 3,251 products and 1,370 days. We find two interrelated phenomena: the bullwhip effect and ration gaming. We estimate that the latter causes the former.

## ■ TA12

North Bldg 126A

### Operations Management for Global Health & Development

Sponsored: Manufacturing & Service Oper Mgmt  
Sponsored Session

Chair: Prashant Yadav, PhD, Harvard Medical School, Seattle, WA

#### 1 - Farmer Engagement with Markets in Rural Uganda

Jarrod D. Goentzel, Massachusetts Institute of Technology, 77 Massachusetts Avenue, E38-650, Cambridge, MA, 02139, United States, Micaela Wiseman, Courtney Blair, Tim Russell

To understand agricultural markets in Uganda, we surveyed farmers and nearby agribusinesses to explore their engagement. We purposively selected 5 districts, randomly chose 2x2km areas, identified households using satellite imagery, and randomly visited households. The survey results characterize behaviors, relationships, and conditions regarding farmer engagement with markets. Further analysis explores the barriers for farmers not connected to the market and how agribusiness help farmers engage in the market. We close with recommendations for market facilitation efforts that support supply chain actors to grow their business and address farmers' challenges.

#### 2 - Estimating Demand of Health Commodities at Rural Chemists in the Absence of Point-of-sale Data

Sripad K. Devalkar, Indian School of Business, Ac3 L1 Room 3114, Hyderabad, 500032, India, Sarang Deo, Aditya Jain, Naireet Ghosh, Shubham Akshat

Adoption of better treatment options in rural areas requires both demand and supply side interventions to increase awareness about the effectiveness of these treatment options and making these commodities accessible. Improving access to health commodities through better replenishment policies requires reliable estimates of demand for such commodities. However, existing methods of demand estimation cannot be used in rural health supply chains due to unavailability of POS data. We overcome this challenge by developing a new methodology that jointly estimates the parameters of the inventory policy of the retailer and the underlying demand distribution by using upstream replenishment data.

#### 3 - Impact of Increased Stock Visibility and Stock Information Sharing on Vaccine Stock Outs in Karnataka India

Anup Akkihal, Logistimo, Seattle, WA, United States, Prashant Yadav, Gaurav Singhal, Vinayak Kothurwar

Impact Of Increased Stock Visibility And Stock Information Sharing On Vaccine Stock Outs In Karnataka India



#### 4 - Does Higher Availability Lead to Higher Use? Understanding the Relationship Between Vaccine Stock Availability and Immunization Coverage in Nigeria.

Prashant Yadav, PhD, Harvard Medical School, Seattle, WA, 98109, United States, Emily Gooding, Eirini Spiliotopoulou

The impact of increases in availability on coverage has not been rigorously evaluated in literature. We use data from Nigeria and a linear mixed effects model to estimate the effect of vaccine availability on routine immunization coverage and to identify factors which affect this relationship. We find that vaccine stockouts significantly decrease the number of children immunized and that for most vaccines, the effect lasts for several months after a stockout. The magnitude of the impact varies by vaccine.

#### 5 - Sourcing Uncertain Product Quality: Competition, Learning, and Volume Postponement

Alexander Rothkopf, Massachusetts Institute of Technology, Cambridge, MA, United States, Felix Lauton, Richard Pibernik

Global-health buyers seek to introduce competition by incenting new generics suppliers with uncertain performance/quality to enter the market. We investigate the benefits of postponing a portion of the award to learn entrant's performance and how the dynamics of learning and competition depend on the size of the postponed volume.

### ■ TA13

North Bldg 126B

#### Joint Session MSOM-Health/APS: Data, Learning, and Decision-Making

Sponsored: Manufacturing & Service Oper Mgmt/Healthcare Operations

Sponsored Session

Chair: Mohsen Bayati, Stanford University, Stanford, CA, 94305, United States

Co-Chair: Khashayar Khosravi, Stanford University

#### 1 - Matrix Completion Methods for Causal Panel Data Models

Khashayar Khosravi, Stanford University, Stanford, CA, United States, Susan Athey, Guido Imbens, Nikolay Doudchenko, Mohsen Bayati

A central tool in empirical operations management is average treatment effect (ATE) estimation from observational data. In this setting, the presence of potential confounders leads to biased estimates of ATE. One way to reduce this bias is to use panel data models where a subset of units is exposed to a binary treatment during some time-periods and the goal is estimating the counterfactual outcomes for all treated units/time-period pairs. We study a class of estimators that minimize the distance between the estimated matrix and the original matrix, while favoring less complex models. We prove the consistency of our estimators by extending the existing results in the matrix completion literature.

#### 2 - Optimized Prediction of Mortality (OPOM): A Novel Machine-learning Approach for Liver Transplant Allocation

Yuchen Wang, Massachusetts Institute of Technology, Cambridge, MA, 02142, United States, Dimitris Bertsimas, Jerry L. Kung, Nikolaos Trichakis, Ryutaro Hirose, Vagefi Parsia

Since 2002, the MELD score has been used to rank candidates for liver transplantation. However, despite numerous revisions, MELD allocation does not allow for fair access to all waitlisted candidates. We developed an Optimized Prediction of Mortality (OPOM) to allow for more equitable allocation of these scarce resources. OPOM uses state-of-the-art machine learning Optimal Classification Tree models that were trained to predict a candidate's three-month waitlist mortality. OPOM exhibited the highest out-of-sample AUC and can decrease 405.92 deaths every year compared to the current rules. Improved survival was noted across all candidate demographics, diagnoses, and geographic regions.

#### 3 - Question-design for Healthcare Plan Recommendation

Jonathan Z. Amar, MIT, 503 Franklin St, Apt 3, Cambridge, MA, United States, Nikos Trichakis, Chaitanya Bandi

We develop a novel question-design mechanism in order to improve healthcare plan recommendations. Our algorithm is based on accurately estimating the differences of utilities associated with every plan. Rather than being agnostic to it, our formulation is driven by available assortment, and therefore achieves better performance for plan recommendation. We establish theoretical justification for our algorithm which outperformed state-of-the-art methods on real datasets.

### ■ TA14

North Bldg 126C

#### Managing Queues: Capacity, Information, and Pricing

Sponsored: Manufacturing & Service Oper Mgmt/Service Operations

Sponsored Session

Chair: Philipp Afeche, University of Toronto, Toronto, ON, M5S 3E6, Canada

Co-Chair: Luyi Yang, Johns Hopkins University, Baltimore, MD, 21202, United States

#### 1 - Pricing and Capacity Decisions for Shared Service Systems Under Competition

Eda Kemahlioglu-Ziya, NC State University, Raleigh, NC, United States, Wei Gu, H. Sebastian Heese, Serhan Ziya

We consider service systems where customers' utility depends on price as well as their service experience, which in turn depends on how crowded the service environment is and who the service environment is shared with. We investigate how two such systems under competition make pricing and capacity decisions under competition.

#### 2 - Managing Two-sided Platforms with Self-scheduling Agents and Impatient Customers

Rouba Ibrahim, University College London, MS&I Department, UCL, Gower Street, London, WC1E 6BT, United Kingdom

We study the operational management of service platforms with self-scheduling agents and impatient customers. Since the customer impatience distribution plays an important role, we propose controlling it using delay announcements, and characterise the interaction between three controls at the manager's disposal: the staffing level, the compensation offered to agents, and the announcements made to customers.

#### 3 - The Economics of Line Sitting

Luyi Yang, Johns Hopkins University, 100 International Drive, Baltimore, MD, 21202, United States, Shiliang Cui

We study an emerging business model of line-sitting in which customers seeking service can hire others (line-sitters) to wait in line on behalf of them. We develop a queueing-game-theoretic model that captures the interaction among customers, the line-sitting firm, and the service provider to examine the impact of line-sitting on the service provider's revenue and customer welfare. We also contrast line-sitting with the well-known priority purchasing scheme as both allow customers to pay extra to skip the wait.

#### 4 - Pricing in a Two-sided Market with Time-sensitive Customers and Suppliers

Philipp Afeche, University of Toronto, Rotman School of Management, 105 St. George Street, Toronto, ON, M5S 3E6, Canada, Mustafa Akan

We consider a firm that matches stochastically arriving and time-sensitive customers and suppliers. We characterize and compare the structure and performance of the profit-maximizing and socially optimal pricing policies.

### ■ TA15

North Bldg 127A

#### Revenue Management and Marketing for Online Retail

Sponsored: Manufacturing & Service Oper Mgmt/Service Operations

Sponsored Session

Chair: David Simchi-Levi, Massachusetts Institute of Technology, Cambridge, MA, 02139, United States

Co-Chair: Clark C. Pixton, Massachusetts Institute of Technology, Cambridge, MA, 02139, United States

#### 1 - E-word of Mouth on Action: Analysis of Operational Decisions when Customers are Resentful

Nesim K. Erkip, Bilkent University, Dept of Industrial Engineering, Ankara, 06800, Turkey, Bahar Cavdar

In this talk, we explore the impact of electronic word-of-mouth (WoM) communication in an online shopping system where there are two types of customers, namely premium and regular customers. Our results reveal insights about the long-run behavior of customer demand and operational decisions under different WoM signals on the perceived quality of different service types and customer behaviors.

## 2 - Understanding the Value of Overlapping Time Windows for Scheduled Delivery Problems

Yeqing Zhou, Columbia University, 550 W. 120th St, New York, NY, 10027, United States, Adam Elmachtoub

We consider a problem where customers choose a delivery time window for a service (such as groceries, laundry, or repair) among a set of options that include small and large time windows. A customer who chooses a large time window receives a reward, while the service provider gains some flexibility. Customers arrive dynamically to the system, and the service provider may dynamically price the time windows. We assume a VRP is solved to satisfy all customers at the end of the horizon. We report on the structure of optimal policies as well as the value of various strategies for designing time windows.

## 3 - Customer Learning for Online Sales of Durable Goods

Clark C. Pixton, Assistant Professor, Brigham Young University, 407 N. 2150 W, Provo, UT, 84601, United States

Motivated by data from a large online retailer, we study online sales of durable goods, focusing on the effects of uncertainty about product quality and learning from customer reviews. We describe the nature of the tradeoff between learning product quality over time and substitution effects between products offered in the same category on the same website. We offer an alternate explanation for market dominance based on transient effects of a learning process which involves decisions under risk, and show that the learning is slower and market dominance more likely in higher price markets. We discuss operational implications for new product timing and incentivizing customer reviews.

## ■ TA16

North Bldg 127B

### Operations in Developing Economies

Sponsored: Manufacturing & Service Oper Mgmt/Sustainable Operations  
Sponsored Session

Chair: Luyi Gui, The Paul Merage School of Business, UC Irvine, Irvine, CA, 92697-3125, United States

#### 1 - Operational Challenges in a Medical Transportation Platform in India

Gonzalo Romero, Rotman, University of Toronto, 91 Ferrier Avenue, Toronto, ON, M4K 3H6, Canada, Andre Du Pin Calmon

A centralized ambulance dispatch center, like 911 in the U.S., does not exist in many developing countries. Therefore, people that need medical transportation must call their local hospital or hire private ambulances. This translates into long waiting times for patients and costly routes for the ambulances. A medical transportation platform can address this problem by aggregating and dispatching life-saving services. Motivated by our ongoing collaboration with a company in India, we model and analyze the operational challenges of managing a healthcare transportation company in an emerging market.

#### 2 - Impacts of Logistics Information on Sales: The Evidence from Taobao

Ying Rong, Shanghai Jiao Tong University, No. 1 Lane 9, Yunwushan Road, Shanghai, 200051, China, Jifeng Luo, Huan Zheng

Leading e-commerce companies are rapidly expanding their logistics networks to deliver items faster and more reliably. This improved logistics quality drives customers to share their positive experiences online. Using a dataset from China's largest e-marketplace platform, we empirically explore the role of logistics services and their effect on online consumer purchasing behaviors.

#### 3 - Supplier Encroachment Deterrence Through Forecasting Scheme Design

Guangrui Ma, Tianjin University, 92 Weijin Road, 25A, CoME, Tianjin, 300072, China, Ying-Ju Chen

We study how a retailer should design its forecasting scheme facing the supplier encroachment risk, under truthful information sharing agreement with its supplier. We identify three different forecasting schemes that should be implemented according to competition intensity between the indirect channel and direct channel, and supplier's channel investment efficiency.

#### 4 - Optimal Subsidy Schemes and Budget Allocations for Government Trade-in Programs

Shu Hu, National Dong Hwa University, 462 Wenyuan Road, Ningbo, 610031, China, Luyi Gui, Jiaru Bai, Zujun Ma, Rick So

This paper develops an analytical framework for designing effective subsidy scheme to motivate consumer trade-ins. We find that a sharing subsidy scheme is always more effective than a fixed subsidy. We further derive analytical results which illustrate how the government should allocate its total available budget for multiple products based on the individual product and market characteristics. Based on the results from our analysis and numerical experiments, we devise a simple budget allocation mechanism that provides near-optimal solutions.

## ■ TA17

North Bldg 127C

### Informational and Reputational Issues in Value Chains

Sponsored: Manufacturing & Service Oper Mgmt/Supply Chain  
Sponsored Session

Chair: Haresh B. Gurnani, Wake Forest University, Winston Salem, NC, 27106, United States

Chair: Saibal Ray, McGill University, Montreal, QC, Canada

#### 1 - Managing Reputation Risk in Supply Chains: The Role of Contract-embedded Insurance

Vibhuti Dhirga, University of British Columbia, 2053 Main Mall, Vancouver, BC, V6T1Z2, Canada, Harish Krishnan

We study the role of contract-embedded insurance in managing a buyer's reputation risk arising due to supplier responsibility violations. We find that insurance can both decrease and increase supplier violations. When insurance reduces violations, the buyer benefits from a lower reputation risk. But if reputation costs are low, the buyer can use insurance to squeeze the supplier's margin even if this increases violations. We then consider the impact of supplier noncompliance on the buying firm's investors. We show that a salary-based compensation for the buying firm's manager is insufficient to align incentives across the three tiers, but risk-based bonus compensation schemes can be effective.

#### 2 - The Informational Role of Buyback Contracts

Haresh B. Gurnani, Wake Forest University, 319 Farrell Hall, School of Business, 1834 Wake Forest Road, Winston Salem, NC, 27106, United States, Shouqiang Wang, Upender Subramanian

Retailers often carry inventory in anticipation of demand. Manufacturers can encourage them to stock sufficient inventory by offering to buyback any unsold inventory at a pre-specified price using a buyback contract. We examine the manufacturer's use of a buyback contract as a signaling mechanism when the retailer is less informed about either the manufacturer's reliability of honoring its buyback commitment or about its product's demand potential.

#### 3 - The Perils of Omniscient Online Retailers

Saibal Ray, McGill University, Desautels Faculty of Management, 1001 Sherbrooke Street W, Montreal, QC, H3A 1G5, Canada, Michelle Y. Lu, Yuxin Chen

With the help of big data technologies, online retailers now become omniscient, i.e., knowing everything about consumer preferences, and product matches between firms and consumers. Online retailers can strategically sell firms information about consumer preferences or withhold matching information but charge firms to reveal them to consumers. Is it good to have such powerful retailers? Our research analyzes this complicated issue and investigates the welfare implications on consumers.

## ■ TA18

North Bldg 128A

### Joint Session BMI/Practice Curated: Empirical Research on Marketplace Innovation

Emerging Topic: Business Model Innovation  
Emerging Topic Session

Chair: Ashish Kabra, INSEAD, Fontainebleau, 77305, France

#### 1 - Do P2P Ride-Hailing Platforms Lead to Pooling or Crowding? Quasi-Experimental Evidence from Uber's Entry in California

Suvrat Dhanorkar, Pennsylvania State University, 466 Business Building, University Park, PA, 16802, United States

Taking advantage of Uber's staggered entry into various geographic markets in California, we execute a regression-based difference-in-difference design to estimate the pooling benefits of ride-sharing services.

#### 2 - Designing Incentives to Scale Marketplaces

Ashish Kabra, INSEAD, Boulevard de constance, Fontainebleau, 77305, France

Marketplace operators run aggressive incentive schemes to achieve scale, that is key to the efficacy, survival and eventual domination of a marketplace. This study quantifies and compares the effect of incentives given to the "buyer side and "seller side using data from a leading ride-hailing market. We build a structural model to accurately capture the driver and passenger response to incentives, and the nature of incentives. Driver effort on the platform is unobserved, for which we devise a novel local matching model based imputation method. We find that in short-term (current week) passenger incentives are more effective while the opposite is true in the long-term (next 3 months).

**3 - Platform and Merchant Interactions in Online-to-offline****Marketplace**

Jiaqi Xu, Carnegie Mellon University, Tepper School of Business,  
5000 Forbes Avenue, Pittsburgh, PA, 15213, United States, Hui Li,  
Sridhar R. Tayur

There are many forms of online platforms that connect local offline merchants to consumers. These business models are referred to as Online-to-Offline (O2O) commerce. We develop a framework to analyze the pricing decision and revenue sharing arrangements between O2O platforms and local merchants. We show that the pricing incentives for the two parties do not align when the revenue sharing arrangement does not fully account for the long-run revenue generated from attracting new consumers. We offer recommendations on how to design the revenue sharing arrangement and discuss the economic viability of various O2O business models observed in practice.

**4 - Surge Pricing Under Spatial Spillover: Evidence from Uber's Operations**

Brad Lee, Boston University Questrom School of Business, 595  
Commonwealth Ave, Boston, MA, 02215, United States, Marcus  
A. Bellamy, Nitin Joglekar

Ride-sharing platforms employ surge pricing to match anticipated capacity spillover with demand. We develop an optimization model to characterize the relationship between surge price and spillover. We test predicted relationships using a spatial panel model on a dataset from Uber's operation. Results reveal that Uber's pricing accounts for both capacity and price spillover. There is a debate in the management community on the efficacy of labor welfare mechanisms associated with shared capacity. We conduct counterfactual analysis to provide guidance in regards to the debate, for managing congestion, while accounting for consumer and labor welfare through this online platform.

**■ TA19**

North Bldg 128B

**Dynamic Preferences in Pricing and RM**

Sponsored: Revenue Management & Pricing

Sponsored Session

Chair: Mikhail Nediak, Queen's University, Kingston, ON, K7L 3N6,  
Canada

**1 - Dynamic Pricing Strategies for Perishable Products**

Cansu Altintas, Eindhoven University of Technology, Technische  
Universiteit Eindhoven P.O. Box 513 Pav.F04, Eindhoven, 5600  
MB, Netherlands, Shaunak Dabadghao, Zumbul Atan, Tarkan Tan

Food waste at the retail level arises for a variety of reasons with expiry of use by date being one of the most common ones. As periodic replenishment practices give rise to the coexistence of units with different expiry dates, customers are inclined to select fresher units which provide a higher perception of quality, as long as there is no price differential. In this study, we consider dynamic discounting as a waste management strategy. We study pricing decisions faced by a retailer selling a perishable product with a shelf life of more than two periods where products with different remaining shelf life can coexist.

**2 - Pricing Decisions when Consumers Have Access to Quality Reviews and the Secondary Market**

Sadegh Kazemi, Washington State University, Pullman, WA,  
United States, Mike Wei, Michelle Wu

We study firm's pricing strategies when quality reviews are available and customers are strategic.

**3 - A Vertical Competition in a Supply Chain with a Cash Constraint Rational Newsvendor Type Retailer and a Supplier Offering Trade Credit**

Meisam Soltani-koopa, Queen's University, Unit 306, 220 Eglinton  
Ave. East, Toronto, ON, M4P 1K4, Canada, Yuri Levin,  
Mikhail Nediak, Anton Ovchinnikov

Trade credit is a form of short-term financing that typically appears as a grace period for invoice payment. We study a supply chain with a supplier and a rational newsvendor type retailer in a form of dynamic Stackelberg game with the supplier as a leader. We examine effects of rationality and ability to make dynamic decisions by both sides and the impact of the cash constraint on the resulting supply-chain outcome. The equilibrium is analyzed using semi-infinite programming approach.

**■ TA20**

North Bldg 129A

**Mechanism Design**

Sponsored: Revenue Management & Pricing

Sponsored Session

Chair: Gabriel Weintraub, Stanford Graduate School of Business,  
Stanford, CA, 94304, United States

**1 - Allocation and Price Guarantees in an Uncertain Internet Advertising Market**

Antoine Desir, INSEAD, Fontainebleau, France, Maxime Cohen,  
Nitish Korula, Balasubramanian Sivan

Buying display ad impressions via auctions in Internet advertising exchanges comes with significant allocation and price uncertainties. We consider the problem of designing a contract to mitigate this risk. In particular, we propose augmenting the traditional auctions with the option of buying at a premium a Market-Maker contract that removes uncertainties in outcome. We rigorously analyze the equilibrium outcome in the presence of a Market-Maker contract and show how to design it to yield an improvement both in the seller's revenue and in the buyer's utilities, therefore improving the total welfare.

**2 - Sequential Procurement through Contractual and Observational Learning**

Gregory Macnamara, Stanford University, Stanford, CA,  
United States, Yonatan Gur, Daniela Saban

We study a dynamic game of incomplete information that models the interactions between a buyer, who demands the same good or service repeatedly over time, and a seller, who can produce the good at a marginal cost and an average quality that are his private information. The quality of the delivered good is stochastic in each time period and unknown in advance. Moreover, the delivered quality is not (objectively) ex post verifiable. We characterize the equilibrium when the buyer makes price offers and identify two forms of learning that may take place with two types of sellers. We identify key parametric regimes which are characterized by different structures of the buyer's optimal learning dynamics.

**3 - The Scope of Sequential Screening with Ex-post Participation Constraints**

Francisco Javier Castro, Columbia University, Columbia School of  
Business, 527 West 121st, New York, NY, 10027, United States,  
Gabriel Weintraub, Dirk P. Bergemann

We study the classic sequential screening problem in the presence of ex-post participation constraints. We establish when the optimal selling mechanism is static (no screening) and dynamic (screening). Our main result establishes a necessary and sufficient condition under which the static contract is optimal and characterize the optimal contract with binary interim types. If the optimal ex-post prices of the interim types are sufficiently close, no screening is optimal. If they are sufficiently apart, screening is optimal. The latter contract randomizes the low type allocation and gives a deterministic allocation to the high type. We also study the optimal contract in the multiple type setting.

**4 - Boosted Second Price Auctions: Revenue Optimization for Heterogeneous Bidders**

Hamid Nazerzadeh, USC Marshall School of Business, Bridge  
Memorial Hall - BRI 401B, 3670 Trousdale Parkway, Los Angeles,  
CA, 90089, United States, Negin Golrezai, Max Lin,  
Vahab Mirrokni

Due to its simplicity and desirable incentive properties, the second price auction has been the prevalent auction format used by advertising exchanges. However, even with the optimized choice of reserve prices, this auction is not revenue optimal when the bidders are heterogeneous and their valuation distributions differ significantly. In order to optimize the revenue of advertising exchanges, we propose an auction format called the boosted second price auction, which assigns a boost value to each bidder. The auction favors bidders with higher boost values and allocates the item to the bidder with the highest boosted bid.



## ■ TA21

North Bldg 129B

### Using Estimation Techniques and Field Experiments to Optimize Operations and Marketing Decisions

Sponsored: Revenue Management & Pricing

Sponsored Session

Chair: Spyros Zoumpoulis, Paris, 75005, France

#### 1 - On the Learning Benefits of Resource Flexibility

Mihalis Markakis, Universitat Pompeu Fabra, Barcelona, Spain,  
Jiri Chod, Nikolaos Trichakis

We consider a firm that acquires resources to sell two products/services. We compare the demand learning under two designs: one with non-flexible resources and one with a single flexible resource. Our analysis reveals that resource flexibility improves learning, unless the products/services have significantly different demand characteristics or economic parameters, leading to an important managerial implication: flexibility is not just the “ability to react;” it also provides better demand information, which can be used pro-actively for better resource planning, pricing, and assortment decisions.

#### 2 - Setting Retail Staffing Levels: A Methodology Validated with Implementation

Santiago Gallino, Dartmouth College, 100 Tuck Hall, Hanover, NH,  
03755, United States, Marshall L. Fisher, Serguei Netessine

We describe a three-step process that a retailer can use in setting retail store sales staff level. First, use historical data on revenue and planned and actual staffing levels by store to estimate how revenue varies with staffing level at each store. We disentangle the endogeneity between revenue and staffing levels by focusing on randomly occurring deviations between planned and actual labor. Second, using historical analysis as a guide, validate these results by changing the staffing levels in a few test stores. Finally, implement the results chain-wide and measure the impact. We describe the successful deployment of this process with a large specialty retailer.

#### 3 - Targeting Prospective Customers Using Field Experiments: Efficient Causal Inference and Robustness of Machine Learning Methods to Data Challenges

Spyros Zoumpoulis, INSEAD, Fontainebleau, France,  
Duncan I. Simester, Artem Timoshenko

We investigate how firms can use the results of field experiments to optimize the targeting of promotions when prospecting for new customers. We propose an approach to designing and analyzing field experiments that has substantive efficiency advantages over standard approaches for experimenting and evaluating targeting policies. We also evaluate seven widely used machine learning methods using a series of two large-scale field experiments, and discuss how well the methods address common data challenges.

#### 4 - Spatial Pricing in Ride-sharing Networks

Kostas Bimpikis, Stanford University, Ozan Candogan,  
Daniela Saban

We explore spatial price discrimination in a ride-sharing platform that serves a network of locations. Riders are heterogeneous in their destinations and their willingness to pay. Drivers decide whether, when, and where to work to maximize their earnings, given the platform's prices. Our findings highlight the impact of the demand pattern on prices, profits, and the induced consumer surplus. We establish that profits and consumer surplus are maximized when the demand pattern is balanced across the network. Also, we show that they both increase with the balancedness of the demand. If demand is not balanced, the platform can benefit substantially from pricing rides differently based on their origin.

## ■ TA22

North Bldg 130

### Design of Online Marketplaces

Sponsored: Revenue Management & Pricing

Sponsored Session

Chair: Kostas Bimpikis, Stanford University

#### 1 - Optimal Pricing in Markets with Non-convex Costs

Navid Azizan, California Institute of Technology, Pasadena, CA,  
United States, Su Yu, Krishnamurthy Dvijotham, Adam Wierman

We consider a market run by an operator, who seeks to satisfy a given consumer demand by purchasing it from a group of suppliers with non-convex cost functions. The operator knows the cost functions and announces a price function for each supplier. Each supplier then makes an individual decision about how much to produce. We propose a new pricing scheme, which is applicable to

general nonconvex costs, and allows using general parametric price functions. The flexibility of our scheme allows finding prices that are typically more economically-efficient and less discriminatory. We supplement the proposed method with a polytime approximation algorithm for finding the optimal quantities and parameters.

#### 2 - Efficiency and Information Aggregation in Heterogeneous Markets

Yaarit Even, Columbia Business School, New York, NY,  
United States, Alireza Tahbaz-Salehi, Xavier Vives

This paper studies how heterogeneous preferences shape the informational and allocative efficiency of centralized markets with asymmetric information. We show that introducing agent-level heterogeneity to the standard rational expectations equilibrium models reduces price informativeness. This reduction in price informativeness in turn manifests itself as an informational externality: in the presence of heterogeneity, agents do not internalize the impact of their trading decisions on the information revealed to others via prices. We conclude by investigating the welfare implications of market segmentation in the presence of this informational externality.

#### 3 - Social Learning with Product Choice

Stefano Vaccari, LUISS University, Via Pietro Ceccato, 15, Roma,  
00156, Italy, Costis Maglaras, Marco Scarsini

We study a model where consumers infer the quality of a set of products through online reviews, and make their subsequent product choice according to an MNL model. Consumers that purchase, write reviews based on their experienced quality. We study the impact of choice on the learning outcome and the speed of learning. We explore the platform display order optimization problem in a setting where consumers have search costs.

## ■ TA23

North Bldg 131A

### Systemic Risk and Network Models

Sponsored: Finance

Sponsored Session

Chair: Zachary Feinstein, Washington University in St. Louis,  
St. Louis, MO

#### 1 - Systemic Risk in a Multilayered Network

Zachary Feinstein, Washington University in St. Louis,  
St. Louis, MO, 63130, United States

In this talk we provide a general framework for modelling financial contagion in a system with obligations in multiple illiquid assets, e.g., currencies. In so doing, we develop a multi-layered financial network that extends the single network of Eisenberg & Noe (2001). In particular, we develop a financial contagion model with fire sales that allows institutions to both buy and sell assets to cover their liabilities and act as utility maximizers. Under standard assumptions, equilibrium portfolio holdings and market prices exist which clear the multi-layered financial system.

#### 2 - A Time-dynamic Eisenberg-Noe Network Model

Tathagata Banerjee, Washington University in St. Louis,  
St. Louis, MO, United States, Alex Bernstein, Zachary Feinstein

We will consider a generalized extension of the Eisenberg-Noe model of financial contagion to allow for time dynamics in both discrete and continuous time. We will provide the derivation and the interpretation of the financial implications. Emphasis will be placed on the continuous-time framework and its formulation as a differential equation driven by the operating cash flows. Mathematical results on existence and uniqueness of firm wealths under the discrete and continuous-time models will be provided. We will discuss the financial implication of the time dynamics with the focus on how the dynamic clearing solutions differ from those of the static Eisenberg-Noe model.

#### 3 - Systemic Risk and Trade Compression

Stephan Sturm, WPI, Department of Mathematical Sciences,  
100 Institute Road, Worcester, MA, 01609, United States

Since the financial crisis 2008 the practice of trade compression has taken off in over-the-counter derivatives markets. We analyze the impact of different trade compression schemes on the systemic risk in derivatives markets.

#### 4 - Systemic Risk Measures and Portfolio Choice

Alexey Rubtsov, Global Risk Institute, Toronto, ON, Canada,  
Agostino Capponi, Alex LaPlante

We develop a model for the optimal portfolio choice in presence of systemic risk. In our modelling approach we use two risk measures: VaR and CoVaR (Adrian and Brunnermeier (2011)). Our investor maximizes portfolios expected returns conditioned on a systemic risk index being at (at most at) its VaR level and portfolios returns below their CoVaR level. Under some assumptions the optimal investment strategy is derived in closed form. The proposed methodology is flexible in balancing the significance of portfolios variance and portfolios correlation with systemic risk index.

## ■ TA24

North Bldg 131B

**Information and Operations Management**

Sponsored: EBusiness

Sponsored Session

Chair: Rakesh Reddy Mallipeddi, Texas A&M University, College Station, TX, 77843-4217, United States

**1 - Buyer and Supplier Perspectives on the Transactional Use of Digital Technologies: Two Sides of the Same Coin?**

Nils Van den Steen, Ghent University, Ghent, 9100, Belgium, Willem Standaert, Steve Muylle, Amit Basu

Prior research has shown that the use of digital technologies can improve the performance of processes involved in supply-chain transactions in a variety of industries. While their impact has been investigated for the procurement process, process-oriented research on the effect of digitization for sales is limited. In addition, both perspectives have not been examined in an integrated and comprehensive way. This study adds to the literature by taking a bilateral perspective on the process performance impact of buyer-supplier transactional use of digital technologies.

**2 - How Much to Open, How Fast to Fix and Develop? Impacts of Open Innovation on New Software Development and Maintenance**

Rakesh Mallipeddi, Texas A&M University, 320 Wehner - 4217, Mays Business School, Dept of Info&Operations, College Station, TX, 77843-4217, United States, Emre M. Demirezen, Subodha Kumar, Ram Gopal

Proprietary software vendors have begun to emulate the open source software community in opening up part of their software to accelerate new product development. In this research, we develop a data-driven model to analytically analyze how open source software, a form of open innovation, affects vendors' software maintenance and new product development strategies.

**3 - Optimizing Surge Pricing Dynamically in Ride Sharing Platforms: A Differential Games Approach**

Samayita Guha, Temple University, Philadelphia, PA, United States, Emre M. Demirezen, Subodha Kumar

The entry of ride-sharing platforms has caused disruptive changes in transportation industry. We use a differential game theory approach to optimize surge pricing for these platforms. We consider how consumers' perception and wait time dynamically influence demand.

**4 - Incentive to Offer Ad Removal in Digital Content**

Lin Hao, University of Notre Dame, 351 Mendoza College Of Business, Notre Dame, IN, 46556, United States

In this paper, we develop a stylized game-theoretic model to study in which market conditions a content provider has the incentive to provide ad removal as an option to its content users. The preliminary results have shown that both the supply-side and demand-side factors playing important roles in determining the equilibrium results.

## ■ TA25

North Bldg 131C

**Best Student Paper Competition – Session III**

Sponsored: Service Science

Sponsored Session

Chair: Aly Megahed, IBM Research-Almaden, San Jose, CA, 95123, United States

**1 - Service Science Best Student Paper Competition**

Aly Megahed, IBM Research - Almaden, San Jose, CA, 95123, United States

This session consists of finalists presentations (judged by an expert panel) to determine the Best Student Paper Award for the Service Science Cluster.

## ■ TA26

North Bldg 132A

**Joint Session Service Science/Practice Curated: Improving Service Operations Using Data Analytics**

Sponsored: Service Science

Sponsored Session

Chair: Weiwei Chen, Rutgers Business School, Piscataway, NJ, 08854, United States

**1 - The Impact of Mobile Payment Channel on Consumer**
**Consumption: Evidence from Alipay**

Yuqian Xu, University of Illinois at Urbana-Champaign, Wohlers Hall 487, 1206 S. 6th St, Champaign, IL, 61820, United States, Anindya Ghose, Binqing Xiao

The rapid development of mobile technology has introduced a new channel for consumer consumption. In this paper, we investigate how mobile payment channel affects other bank payment channels. We utilize a unique data set from one of the largest bank in China, which contains the consumer credit card consumption from online, offline, and mobile payment channels. We find the transaction amount increases around 2.4% after Alipay adoption, and the transaction frequency increases around 23.5%. Furthermore, we find Alipay channel acts as a substitute for the offline (physical card) channel, and a complement for the online banking channel.

**2 - Improving Patient Flow in the Presence of Heterogeneous Patient Types**

Woo-Hyung Cho, Cornell University, Ithaca, NY, United States, Shane Henderson, David B. Shmoys

Outpatient medical facilities face a challenging scheduling and resource allocation problem given heterogeneous streams of patients competing for the same resources. We are working with a large breast imaging facility in NYC, where different patient types experience a nested service requirement. Through analyses of patient timestamp data, we identify potential bottlenecks in the system and examine strategies to systematically take advantage of underutilized resources. We use a data-driven discrete-event simulation model to measure the impact of implementing our proposed strategy under various scenarios.

**3 - The Impact of Competition on Hospitals' Progression Towards Meaningful Use**

Varun Gupta, Penn State Erie, The Behrend College, 5101 Jordan Rd, Burke 281, Penn State Erie, The Behrend College, Erie, PA, 16563, United States, Xin Ding, Xin Ding, Ozgun Demirag

In this paper, we examine how competition in local hospital service area drives hospitals' decision to move along the meaningful use stage model with performance data from 2011 to 2015. Additionally, we develop a series of hypotheses based on game theory and test the hypotheses with the performance data in econometric models.

**4 - Rebalancing Bike Sharing Systems: A Data-driven Approach**

Weiwei Chen, Rutgers Business School, 100 Rockefeller Road, Supply Chain Management, Piscataway, NJ, 08854, United States, Junming Liu, Leilei Sun, Hui Xiong

Bike sharing systems aim at providing the missing links in public transportation systems and have become increasingly popular worldwide. Due to geographical and temporal unbalance of bike usage demand, bikes need to be reallocated among stations so as to maintain a high service level of the system. This talk introduces a data-driven hierarchical optimization methodology, including bike demand predictors and a clustering-based decomposition optimizer, in solving this daily operational problem of bike sharing systems. Numerical experiments using data from NYC, Chicago and Boston show the accuracy of the demand predictors and the effectiveness of the optimizer.

## ■ TA27

North Bldg 132B

**Keeping it Real: In-demand Skills in BI Curricula**

Sponsored: Education (INFORMED)

Sponsored Session

Chair: Ruben A. Mendoza, Saint Joseph's University, Philadelphia, PA, 19131, United States

**1 - The Rise of Data Literacy**

Jordan Morrow, Qlik, Bountiful, UT, United States

With the growing desire of organizations to utilize data to drive insight and decisions, individuals need to be empowered with skills in data literacy. Join this session to learn about the world of data literacy and how individuals and organizations can help drive skills to help everyone succeed in the analytics economy.

## 2 - Understanding Gaze Events and Brain Activities in Online-learning through Electroencephalography and Eye-tracking

Yuzhi Sun, Oregon State University, 1500 SW Jefferson St., Corvallis, OR, 97331, United States, David Nembhard

We investigated the degree to which gaze events and brain activities are predictive of individual online learning performance through 2-by-2 experiment. Through the research, the gaze events were taped and documented via eye-tracking, the brain activities were monitored and recorded by the electroencephalogram (EEG), and the quiz scores measured the learning performance. ANOVA models and SEM models were considered to examine the relationships. Notably, the models indicate that there exists a significant association between design factors, gaze event durations, and learning outcomes. Levels of correlation between brain activities and gaze events were also found.

## 3 - Optimal Weighting for Exam Composition

Sam Ganzfried, Ganzfried Research, 1504 Bay Road, Apt. 1706, Miami Beach, FL, 33139, United States, Farzana Beente Yusuf

A problem faced by many instructors is that of designing exams that accurately assess the abilities of the students. Typically, generic question scores are used based on rough approximation of the question difficulty and length. We describe a novel framework where algorithms from machine learning are used to modify the weights to optimize the exam scores, using the overall final score as a proxy for a student's true ability. We show that significant error reduction can be obtained by our approach over standard weighting schemes. We make several new observations regarding the properties of the "good" and "bad" exam questions that can have an impact on the design of improved future evaluation methods.

## ■ TA28

North Bldg 221A

### Resilient Rail and Failure Prediction

Sponsored: Railway Applications

Sponsored Session

Chair: Nikola Besinovic, Delft University of Technology, Delft, 2600CN, Netherlands

#### 1 - Train Rescheduling and Circulation Planning in Case of Complete Blockade for an Urban Rail Transit Line

Yihui Wang, Beijing Jiaotong University, Beijing, China, Lingyun Meng, Tao Tang, Bin Ning

With the rapid development of urban rail transit system, the disruptions occur more frequently due to the uncertain factors, such as signal failures. Once a disruption is occurred, the passengers' safety and travel efficiency are seriously affected. Moreover, this impact of the disruption may spread to the adjacent lines and even to the whole network. Train rescheduling has a great effect on evacuating passengers quickly and relieving the mismatch of transport capacity and traffic volume. To maintain the transport capacity as much as possible under the disruption scenarios, this paper considers the train rescheduling and circulation planning in case of complete blockade for an urban rail line.

#### 2 - Modelling Resilience of Rail Transport Networks

Nikola Besinovic, Delft University of Technology, Stevinweg 1, Delft, 2600CN, Netherlands

In current railway system disruptions are inevitable and more, their number is expected to further increase making the system even more vulnerable. We propose resilience performance indicators (RPI), to accurately estimate system performance during disruptions. We consider both topological and operational causes such as infrastructure and rolling stock failures. In addition, the effects of both single and multiple disruptions are investigated. For this purpose, historical traffic data from the Netherlands is used. As an outcome, we determine the most efficient RPI and a set of the most critical disruptions, which can be used in evaluating and optimizing resilience of future railway systems.

#### 3 - Predicting Locomotive Failures: A Machine Learning Approach

Clark Cheng, Sr. Director Operations Res & Chief Data Scientist, Norfolk Southern Corporation, 1200 Peachtree Street NE, Mail Stop 171, Atlanta, GA, 30309, United States, Mabby Amouie, Ilya Lavrik

Locomotive reliability is a mission-critical issue for freight railroads. A locomotive failure will likely cause train delay, line-of-road congestion, service disruption, and ripple effect across the rail network. In this presentation, we'll describe a machine-learning approach to predicting locomotive failures using sensor data ingested from locomotives.

## 4 - Modeling and Predicting Recurrent Rail Defects

Faeze Ghofrani, University at Buffalo, SUNY, Buffalo, NY, United States, Qing He, Reza Mohammadi

Provided six-year data from a US Class I railroad, this study develops a robust methodology for predicting the recurrence of rail defects at the same location by using the conditional frailty cox model. The results of this study are useful for railroads to develop effective strategies for track corrective maintenance to reduce the recurrence of rail defects.

## 5 - Positioning and Coordination of Resources for Reliable Emergency Response to Railroad Incidents

Yanfeng Ouyang, U. of Illinois at Urbana-Champaign, 205 N. Mathews Ave, 1209 Newmark Lab, MC-250, Urbana, IL, 61801, United States, Siyang Xie

This talk discusses strategic positioning and allocation of emergency response resources that may be impacted by rail incidents. Mathematical models and solution techniques are developed to systematically analyze the emergency response system in case: (i) joint dispatches are needed from multiple locations, and (ii) the emergency response system itself is vulnerable; e.g. due to blockage of railroad crossings after the incident.

## ■ TA29

North Bldg 221B

### Market Design Approaches for Transportation Systems

Sponsored: TSL/Urban Transportation

Sponsored Session

Chair: Changhyun Kwon, University of South Florida, Tampa, FL, 33620, United States

#### 1 - Spatio-temporal Pricing for Ridesharing Platforms

Hongyao Ma, Harvard University, 33 Oxford Street, MD 242, Cambridge, MA, 02138, United States, Fei Fang, David C. Parkes

A challenge in dynamic pricing in ridesharing platforms is to set prices that are appropriately smooth in space and time, so that drivers will choose to accept their dispatched trips, rather than drive to another area or wait for a better trip. We introduce the Spatio-Temporal Pricing (STP) mechanism, which is subgame-perfect incentive compatible for drivers, and also welfare-optimal, envy-free, individually rational and budget balanced from any history onward. We prove that there can be no dominant-strategy mechanism with the same economic properties, and show via simulation that STP achieves significantly higher social welfare than a myopic pricing mechanism, where drivers have high regret.

#### 2 - Combinatorial Auction with Bidder-defined Items for Fractional Ownership of Autonomous Vehicles

Mahdi Takaloo, Tampa, FL, 33613, United States, Aigerim Bogyrbayeva, Hadi Charkhgard, Changhyun Kwon

In this study, a combinatorial auction with bidder defined items is proposed to design a market for vehicle fractional ownership under autonomous vehicles. Considering spatial information of bidder, we formulate the winner determination problem for the proposed combinatorial auction market under both discrete- and continuous-time settings. We show that the continuous-time model is superior, in terms of social welfare maximization, to the discrete-time model. We provide a clique-based reformulation of the continuous-time model, for which we develop an efficient algorithm.

#### 3 - Acyclic Mechanism Design for Freight Consolidation

Wentao Zhang, 3715 McClintock Ave, GER 240, Los Angeles, CA, 90089, United States, Nelson A. Uhan, Maged M. Dessouky, Alejandro Toriello

Freight consolidation is a logistics practice that improves the cost-effectiveness and efficiency of transportation operations, and also reduces energy consumption and carbon footprint. A "fair" shipping cost sharing scheme is indispensable to help establish and sustain the cooperation of a group of suppliers in freight consolidation. We design a truthful acyclic mechanism to solve the cost-sharing problem in a freight consolidation system. We study the budget-balance of the mechanism both theoretically and numerically. We also study the economic efficiency of our mechanism numerically to investigate its impact on social welfare.

#### 4 - American Options-Based Collaboration Mechanism for Multiple Less-Than-Truckload Carriers Under Demand Uncertainty

Choungyeol Lee, Purdue University, West Lafayette, IN, United States, Srinivas Peeta

We propose an American freight options-based collaboration mechanism for multiple less-than-truckload carriers that provides the flexibility to exercise the options at any time up to the expiry date so as to enhance operational efficiency. The proposed mechanism can address demand uncertainty by allowing for cost-efficient capacity allocation adjustments depending on future demand realization. Results of numerical experiments show that the proposed mechanism enables the collaborating carriers to enhance capacity utilization and profitability, while leveraging excess capacity in a more cost-efficient manner.



## ■ TA30

North Bldg 221C

### Transportation Aspects Towards a Smart City

Emerging Topic: Smart Cities

Emerging Topic Session

Chair: Stephen Mattingly

#### 1 - The Marginal Congestion of a Taxi in New York City

Alejandro Molnar, Asst Professor, Vanderbilt University,  
415 Calhoun Hall, Nashville, TN, 37240, United States,  
Daniel Mangrum

We exploit the partial deregulation of New York City taxi medallions to provide a causal estimate of the impact of taxi supply on congestion. We employ taxi trip records to measure historical street-level speed. We find that the roll-out of newly authorized taxis caused a local 8-9% decrease in speed. We estimate an empirical congestion elasticity curve from heterogeneous changes in speed and taxi supply, counted from aerial orthoimagery. Additionally, we provide novel urban sensor data to document a substantial traffic slowdown since 2013. Most of the slowdown in midtown Manhattan is accounted for by new supply from ridehail applications.

#### 2 - Integrating Transportation Education and Research for Smart Cities

Ruey Cheu, University of Texas at El Paso, El Paso, TX,  
United States, Miroslav Svitek, Tomas Horak

The concept of smart cities requires professionals in different disciplines to work together and engaging the community, but there is a lack of such education program. In this presentation, the speakers will examine the strength and weaknesses of discipline specific transportation education programs in universities. They will then discuss several smart cities education and research initiatives at The University of Texas at El Paso (UTEP) and Czech Technical University (CTU) at undergraduate, graduate and PhD levels. They will next share their experience in transforming the dual master degree program in transportation between UTEP and CTU, to a new dual master degree program in smart cities.

#### 3 - Decentralized Optimization of Urban Traffic Flows

Stephen F. Smith, Carnegie Mellon University, Robotics Institute,  
Carnegie Mellon University, Pittsburgh, PA, 15213, United States

Recent work in decentralized, schedule-driven traffic signal control has produced a promising new approach to traffic flow optimization in urban road networks. This approach, which relies on a novel formulation of the intersection control problem as a special type of single machine scheduling problem, has yielded significant efficiency improvements in initial field deployments. In this talk, we describe current research aimed at broadening network-level optimization performance through use of queueing theory concepts, more expressive problem representations, and bi-directional information exchange.

#### 4 - I-STREET Testbed: Progress and Challenges

Clark Letter, University of Florida, Gainesville, FL, United States,  
Lily Elefteriadou

The University of Florida and its Transportation Institute (UFTI), the Florida Department of Transportation and the City of Gainesville have coordinated the development of a smart testbed on the UF campus and adjoining city streets. The testbed is established to deploy and evaluate numerous advanced technologies including connected and autonomous vehicles, smart devices, and sensors, as well as to develop novel applications for their use. Many challenges arise when deploying new technologies, and I-STREET hopes to share lessons learned with other agencies.

## ■ TA31

North Bldg 222A

### Integration of Learning Approaches and Emerging Traffic Operation and Control Technologies

Sponsored: TSL/Intelligent Transportation Systems (ITS)

Sponsored Session

Chair: Lili Du, University of Florida, 2550 Yeager Road, Gainesville, FL, United States

#### 1 - Clustering Based Mixed Strategy Coordinated In-vehicle Routing for Connected and/or Autonomous Vehicles

Wang Peng, University of Florida, Gainesville, FL, United States

This study develops a clustering based mixed strategy coordinated in-vehicle routing approach. Specifically, this study develops graphical and network flow approaches to evaluate the direct and indirect competition potential among

multiple travelers on network route resources. Furthermore, we design an adaptive centroid-based clustering algorithm to find a local optimal clustering solution. Built upon that, a mixed strategy coordinated routing mechanism is implemented to coordinate in-vehicle routing decisions for multiple traveler clusters over a large scale network. The numerical experiments are conducted to validate the efficiency and applicability of the proposed approaches.

#### 2 - Macroscopic Traffic Flow Modeling with Mixed Connected and Human-driven Vehicles

Xianfeng (Terry) Yang, University of Utah, Salt Lake City, UT,  
United States, Zhehao Zhang, Zhao Zhang

Although connected vehicles (CVs) will soon go beyond testbeds, it can be expected that CVs and human-driven vehicles (HVs) will co-exist over a long period. Due to the capability of exchanging data, CVs behave differently compared with HVs. In this study, we aim to develop a macroscopic traffic flow model to understand how speed change of CVs would impact HVs in the traffic stream. Particularly, friction factors are introduced to the speed formulations for accounting interactions between CVs and HVs. Then extended Kalman Filter is employed to update both model parameters and friction factors in real-time. For model evaluation, we employ simulated data as ground truth for conducting numerical tests.

#### 3 - Information Dissemination Dynamics via Vehicle-to-vehicle Communication over Transportation Networks

Ala S. Alobeidyeen, University of Florida, Gainesville, FL,  
United States

The study developed a discrete mathematical model to track information spreading dynamics via V2V over an urban transportation network at discrete time steps. Specifically, an information network flow combined with the IT-CTM (Du et al., 2016) is developed to respectively track traffic information wave spreading dynamics at traffic intersections and road segments. Moreover, machine learning approach is used to investigate the correlation between information coverage and traffic congestion based on simulation experiments.

#### 4 - Online Demand-driven Car Sharing Rebalancing

Xiaopeng Li, University of South Florida, 4202 E. Fowler Avenue,  
Tampa, FL, United States, Dongfang Zhao

This study proposes an online car-sharing rebalancing model to deal with the car sharing fleet management problem using reinforcement learning. We develop a multi-agent reinforcement learning framework using a deep Q-learning algorithm. The goal of the algorithm is to maximize the total profit of the platform by repositioning available cars to the locations with outstanding demand-supply gaps. This model does not make any assumption on the demand and is completely driven by spatially distributed demand data history. With real-world data, we show significant improvements of the proposed framework over state-of-the-art approaches through extensive empirical studies.

## ■ TA32

North Bldg 222B

### Same-day Delivery

Sponsored: TSL/Freight Transportation & Logistics

Sponsored Session

Chair: Niels Agatz, Erasmus University, Rotterdam, Netherlands

#### 1 - Splitting Pickup and Delivery Tasks in a Same-day Personal Shopper Service

Alp Arslan, Erasmus University Rotterdam, Admiraliteitskade  
50-713, Rotterdam, 3062ED, Netherlands, Niels Agatz,  
Mathias A. Klapp

We consider a same-day personal shopper service that receives customer delivery requests that require pickups at one or more stores. All requests that can be served in their requested time window are accepted. We study the benefits of splitting a single customer request into various delivery tasks served by different shoppers to improve the percentage of customers served throughout the day.

#### 2 - Tactical Design of Same-day Delivery Systems

Alex Stroh, Georgia Institute of Technology, Atlanta, GA, 30332,  
United States, Alan Erera, Alejandro Toriello

We study tactical designs for same-day delivery (SDD) systems. We look for structure in optimal dispatch policies when a SDD system is modeled with smoothed customer demand and vehicle route durations are approximated by a continuous time function of the number of customers served. Using these optimal policies, we study tactical decisions for SDD systems which prior research has used as model inputs. Specifically, we can answer questions like: How large of a fleet is required? When during a service day should a retailer stop accepting same-day orders? How often can a retailer expect to dispatch delivery vehicle? We illustrate our findings with a set of realistic examples.

### 3 - Provably High-quality Solutions for the Meal Delivery Routing Problem

Baris Yildiz, Asst.Prof., Koc University, Rumeli Feneri Yolu, Sariyer, Istanbul, 34450, Turkey, Martin W. P. Savelsbergh

Meal delivery is arguably the ultimate challenge in last mile logistics: a typical order is expected to be delivered within an hour (much less if possible), and within minutes of the food becoming ready. We introduce a novel formulation for a meal delivery routing problem in which we assume perfect information about order arrivals, and develop a simultaneous column and row generation method for its solution. The analysis of our extensive computational study, using instances derived from real-life data, demonstrates the efficacy of the solution approach, and provides valuable insights into, among others, the (potential) benefits of order bundling, courier shift scheduling, and demand management.

### 4 - Shuttle Scheduling for Same-day Courier Service

Iman Dayarian, Culverhouse College of Commerce, The University of Alabama, Box 870226, Tuscaloosa, AL, 35487, United States, Adolfo Antonio Rocco Rocco, Martin W. P. Savelsbergh

We consider data-driven design of an intra-city logistics service network of an express courier company, offering same- and next-day delivery services. The system is designed on a multi-layer network. At the lowest level, the couriers are responsible for pick-up and delivery of the packages at the customer locations. In an intermediate level network, the riders are responsible for transferring packages between couriers and local hubs where, the shipments are sorted, consolidated, and transferred to their destination local hubs through a network of shuttles. Our goal is to design shuttle routes and schedules that guarantee on-time delivery of same-day packages, given the dynamic nature of demand.

## ■ TA33

North Bldg 222C

### Advances in Traffic Flow Modeling

Sponsored: TSL/Intelligent Transportation Systems (ITS)

Sponsored Session

Chair: Dianchao Lin, New York University, New York University, New York, NY, United States

#### 1 - A Car Following Model Incorporating Reaction Time Dynamics Online Calibration and Case Study

Kerem Demirtas, Arizona State University, 699 S. Mill Ave. Tempe, Brickyard Engineering 553, Tempe, AZ, 85281, United States, Pitu B. Mirchandani, Xuesong Zhou

In this study, we are interested in online calibration of car following parameters to explore both inter-driver and intra-driver heterogeneity. Specifically, we offer an augmented state space system for a lower order linear spacing car following model, and implement a modified Kalman filter algorithm to track the leader-follower pairs and simultaneously predict and estimate the parameters related with the behavior of the followers. Three different state transition models are proposed which incorporate reaction time dynamics exploiting instantaneous local density information. Comparison and interpretation of the results, and promising future research directions are given.

#### 2 - Modeling Flood Dynamics: Interacting Processes between Transportation and Water Networks

Cesar N. Yahia, The University of Texas at Austin, Austin, TX, 78705, United States, Isha Deo, Stephen D. Boyles, Paola Passalacqua

We model real-time flood dynamics by considering the influence of hydrologic terrain and processes on the transportation network. We propose a data-driven model that integrates information from multiple sensors. This enables short range predictions on the disruption state of the transportation network.

#### 3 - Stochastic Fluid Queuing Model for Evaluating Smart Highway Operations

Li Jin, Assistant Professor, New York University, Brooklyn, NY, United States, Saurabh Amin, Patrick Jaillet

We present a stochastic, finite-buffer fluid queuing model of serially connected highway segments that serve a mix of normal traffic and connected vehicle platoons. The queuing dynamics is governed by a Markov chain, which models capacity perturbations (due to incidents), and/or randomness in platoon integration. We derive a necessary condition and a sufficient condition for the stability of this system, and analyze the sensitivity of expected throughput under various operational scenarios. Our analysis provides novel insights for incident management and vehicle platooning operations.

#### 4 - Lane-change Strategies for Connected Vehicles Using Cooperative Game Theory

Dianchao Lin, Ph.D Candidate, New York University, New York, NY, United States, Li Li, Saif Eddin G. Jabari

This paper proposes two new lane changing strategies to serve connected vehicles using cooperative game theory: transferable utility strategy which allows vehicles to transact lane usage timely using transferable utility solution, and the non-transferable utility strategy using Nash bargaining solution. Simulations using

Cellular Automata are employed to explore the impact of transaction vehicles percentage, traffic density and value of time. Results showed that, cooperation between drivers could help achieve win-win result. Besides, a properly designed utility function could encourage vehicles to participate in transactions, and prevent them from cheating in their value of time.

## ■ TA34

North Bldg 223

### 7:30 - 8:15 Mem Computing Inc./ 8:15 - 9:00 Palisade

Vendor Demo Session

#### 1 - Overview of MemComputing Inc.

Mem Computing, Mem Computing Inc., La Jolla, CA, United States

Companies in all industries are seeking to optimize the efficiencies of their business environments in order to stay competitive. Data science is now coming to the forefront across departments as they seek ways to leverage big data collections to implement solutions for improved efficiency and profitability. There are a set of problems associated with optimization, big data analytics and operations research among other areas, where companies are having to accept less than the optimal answer. The challenge lies within the fact that the size and complexity of the problems will grow exponentially as the inputs and constraints grow linearly. To find viable solutions, alternative methods are employed such as reducing the amount of data analyzed, breaking the problem up into smaller problems or accepting an incomplete answer when time reaches the threshold. This is not advantageous nor is it economical as efficiencies, innovations and revenues decline. This tutorial presents a novel coprocessing architecture that is shifting the computing paradigm. Based on novel technology developed by MemComputing, Inc. its MemCPU Coprocessor platform speeds up computational time solving and finding accurate solutions for complex optimization and combinatorial problems of high economic value.

#### 2 - Quantitative Risk Analysis in Excel with @RISK

Jos Ra-I Castro, Palisade Trainer/Consultant, Palisade Corporation, Ithaca, NY, United States

This tutorial will guide you in the use of @RISK for analyzing historical data and making better decisions in an uncertain business environment. @RISK is part of Palisade's Decision Tools Suite and runs as an add-in for MS Excel. It provides all the features you need to quantify and understand risks with the support of Monte Carlo Simulation, including graphical capabilities and quick reports to help you present results to a non-technical audience.

## ■ TA35

North Bldg 224A

### Joint Session AAS/Practice Curated: UAS Applications and Optimization

Sponsored: Aviation Applications

Sponsored Session

Chair: Maga Khachatryan, MagAnalytics, 3883 Park Place Estates Dr., Bridgeton, MO, 63044, United States

#### 1 - Optimization of Grid Coverage Operations in Flight Aerial Imagery Data Collection

Maga Khachatryan, MagAnalytics, St. Louis, MO, United States, Ara Nefian, Naira Hovakimyan

Today, we live in the age of digital revolution which impacts modern agriculture. Every season farmers cultivate millions of acres leveraging technologies such as IoT, drones and satellites. Along with benefits technology also brings challenges. Particularly, cost of aerial imagery throughout growing season can be very high. One of the most common imagery delivery methods are airplanes. Here we describe two-stage airplane routing problem with business constraints. First stage reduces the solution space by generating flight patterns to allow faster second-stage optimization. The second stage optimizes airplane flight schedule by selecting most profitable patterns to fly over farming area.

#### 2 - Opportunities and Challenges of Integrating UAS in the US

Dipasis Bhadra, Economist, Federal Aviation Administration, 800 Independence Avenue 935-937, Washington, DC, 20591, United States, Michael Lukacs

UAS has become one of the most vibrant sector of the economy in the US. With over a million registered owners/operators, the sector holds promises that span over commercial applications of numerous types to personal recreational uses. While the challenges are many, the FAA has launched various initiatives ranging from pilot programs to regulatory reforms integrating UAS into NAS. An active research program undertaken by the Agency facilitates these activities ensuring safe integration of UAS into the National Airspace System (NAS). This presentation will broadly touch on Agency's outlook of the future, activities that are presently undertaken and the challenges/opportunities that lie ahead.

### 3 - Impact Of Payload Amount On Battery Consumption Rate In a Delivery Application Of Drones

Maryam Torabbeigi, University of Houston, UH, Houston, TX,  
United States, Gino J. Lim, Seon Jin Kim, Navid Ahmadian

The drone battery charge limitation is an important factor in drone scheduling in order not to run out of battery during the flight. This study investigates the relationship between battery consumption rate (BCR) and the payload amount, and also the impact of payload amount (customer's demand) on the drone scheduling. The collected data verifies a linear relationship between BCR and the payload amount. A routing problem is proposed for the drone scheduling. The model determines the number of drones, their path, the assigned customers, and the battery charge at each flight segment. The results show the impact of including BCR in the scheduling.

### 4 - Multiobjective Uav Route Planning In Continuous Terrain Using a Preference-based Evolutionary Algorithm

Murat Mustafa Koksalan, Middle East Technical University,  
Industrial Engineering Department, Ankara, 06531, Turkey, Erdi Dasdemir, Diclehan Tezcaner Ozturk

Multiobjective route planning for unmanned air vehicles (UAV) in continuous terrain involves determining the visiting order of targets and the trajectories used between target pairs under multiple objectives. In this research, a hybrid heuristic approach is developed. Order of targets are first determined with a preference-based evolutionary algorithm converging to the desired regions of the Pareto-optimal frontier using the decision maker's preferences. Then the trajectories between target pairs are found with a heuristic approach using the results of the evolutionary algorithm. The algorithm is implemented on several problems and results are promising.

## ■ TA36

North Bldg 224B

### Joint Session Drones/Practice Curated: Drones in Logistics

Emerging Topic: Robotics, Drones and Autonomous Vehicles in Logistics

Emerging Topic Session

Chair: James F. Campbell, University of Missouri-St Louis,  
Saint Louis, MO, 63121-4499, United States

#### 1 - Coordinated Logistics with a Truck and a Drone

John Gunnar Carlsson, University of Southern California, 3750  
McClintock Avenue, Los Angeles, CA, 90089, United States

We determine the efficiency of a delivery system in which an unmanned aerial vehicle (UAV) provides service to customers while making return trips to a truck that is itself moving. In other words, a UAV picks up a package from the truck (which continues on its route), and after delivering the package, the UAV returns to the truck to pick up the next package. By combining a theoretical analysis in the Euclidean plane with real-time numerical simulations on a road network, we demonstrate that the improvement in efficiency is related to the square root of the ratio of the speeds of the truck and the UAV.

#### 2 - Optimization of a Drone-aided Network

Bahar Kara, Bilkent University, Department of Industrial Eng,  
Ankara, 06800, Turkey, Aysu Ozel, Oya Ekin Karasan

Integrating drones into delivery networks has advantages such as reduced delivery times, costs and access to hardly reachable points. However, due to the limited abilities of drones, it is not possible to deploy solely drones in delivery networks. Thus, drones should be collaborated with the traditional delivery vehicles and this collaboration requires synchronization between drones and delivery vehicles. In this study we propose a mixed integer mathematical model minimizing the time of the last delivery in a network in which a drone and a truck works in synchronization.

#### 3 - Mothership and Drone Routing Problems

Bruce L. Golden, University of Maryland-College Park, 10375  
Eclipse Way, Columbia, MD, 21044, United States,  
Stefan Poikonen

The Mothership and Drone Routing Problem considers a tandem between a ship and a drone. The drone is required to visit each of a set of targets. However, the drone has finite battery life and, thus, must coordinate with the ship. The problem combines elements of combinatorial optimization and continuous optimization. Second order cone programming is used in a proposed solution method that is flexible to adapt to alternative objective functions and constraint sets. We then consider several generalizations.

## ■ TA37

North Bldg 225A

### Data Science and Applied Probability

Sponsored: Applied Probability

Sponsored Session

Chair: Gah-Yi Ban, London Business School, London Business School,  
London, NW1 4SA, United Kingdom

#### 1 - Statistical Inference for Model Parameters with Stochastic Gradient Descent

Xi Chen, New York University, New York, NY, 10012,  
United States, Jason Lee, Xin Tong, Yichen Zhang

In this talk, we investigate the problem of statistical inference of model parameters based on stochastic gradient descent (SGD). To this end, we propose a consistent estimator of the asymptotic covariance of the average iterate from SGD — batch-means estimator, which only uses the iterates from SGD. As the SGD process forms a time-inhomogeneous Markov chain, our batch-means estimator with carefully chosen increasing batch sizes generalizes the classical batch-means estimator designed for time-homogeneous Markov chains. The proposed batch-means estimator allows us to construct asymptotically exact confidence intervals and hypothesis tests.

#### 2 - Assessing the Spillover Effect on Delivery Time: An Empirical Study on a Logistic Platform

Yifan Feng, The University of Chicago Booth School of Business,  
5807 S. Woodlawn Avenue, Chicago, IL, 60637, United States,  
Rene A. Caldentey, Linwei Xin

Our study is based on a dataset from a major logistics platform for e-commerce business in China. We quantify the spillover effects on delivery time and demonstrate its relationship with the philosophy of complete resource pooling (CRP).

#### 3 - Validating Optimization Under Uncertainty

Henry Lam, Columbia University, 500 W. 120th St., New York, NY,  
10027, United States, Huajie Qian

Optimization formulations to handle decision-making under uncertain constraints, such as (distributionally) robust optimization, often contain parameters that control the level of conservativeness. We investigate strategies to select parameter values by validating their performances in terms of both feasibility and optimality. We demonstrate the effectiveness of these strategies in relation to the optimization class and problem dimension.

#### 4 - Confidence Intervals for Data-driven Inventory Policies with Demand Censoring

Gah-Yi Ban, London Business School, Regent's Park, London,  
NW1 4SA, United Kingdom

We revisit the classical dynamic inventory management problem of Scarf (1959) from the perspective of having  $n$  historical selling seasons of data and making ordering decisions for the upcoming season. We develop a nonparametric estimation procedure for the  $(S; s)$  policy that is consistent, then characterize the finite-sample properties of the estimated  $(S; s)$  levels by deriving their asymptotic confidence intervals. We also consider having at least some of the past selling seasons of data censored from the absence of backlogging. We then show how to correctly use the censored data to obtain consistent decisions and derive asymptotic confidence intervals for this policy using Stein's method.

## ■ TA38

North Bldg 225B

### Joint Session APS/Practice Curated: Bandits, Optimal Stopping, and Control

Sponsored: Applied Probability

Sponsored Session

Chair: David Goldberg, Cornell University, Ithaca, NY, 14850,  
United States

#### 1 - Recent Progress at the Intersection of Optimal Stopping and Bandits

Yilun Chen, Cornell, 292 Rhodes Hall, Ithaca, NY, 14853,  
United States, David Goldberg

We present progress on the problem of optimal stopping, and its application to bandits. We develop a new pure-dual algorithm for optimal stopping, which leads to an expansion (for the optimal value) in which each term has a natural representation in terms of certain (infima of) conditional expectations, and can enable better approximation with fewer nested conditional expectations. For Bayesian bandits, we present several novel insights into the (optimal) Gittins index policy, shedding light on what, qualitatively, makes the Gittins index policy truly optimal, as compared to other policies optimal only w.r.t. (asymptotic) first-order regret.



**2 - Sequential Search For The Best Alternatives**

David Brown, Duke University, Fuqua School of Business, 100 Fuqua Drive, Durham, NC, 27708, United States, Santiago Balseiro

We consider a variation of the sequential search problem studied in Weitzman (1979), where a DM sequentially searches a given set of alternatives with unknown rewards, drawn from independent distributions. Search is costly but reveals the rewards of an alternative. The DM can select previously revealed alternatives and collect the associated rewards. We study a variation in which the DM has the capacity to select multiple alternatives, which significantly complicates the problem. We consider a simple reservation price rule, with reservation prices depending only on the remaining capacity and show that the policy is asymptotically optimal as the number of alternatives grows large.

**3 - On Learning the C Rule**

Subhashini Krishnasamy, Tata Institute of Fundamental Research, Mumbai, 400005, India, Ari Arapostathis, Ramesh Johari, Sanjay Shakkottai

We study the  $c$  rule for multi class queueing systems. When the service rates are known, the  $c$  rule is known to minimize the expected holding cost over any fixed time horizon in the single server setting. For a parallel server network, we demonstrate that the  $c$  rule does not ensure stability. We present sufficient conditions for the stability of the  $c$  rule for a general parallel server network and also necessary and sufficient conditions for a specific class of parallel server networks. When the service rates are unknown, we propose, both for single and parallel server networks, algorithms using empirically learned service rates that achieve a holding-cost regret that does not depend on the time horizon.

**■ TA39**

North Bldg 226A

**Non-stationary Stochastic Networks with Information**

Sponsored: Applied Probability

Sponsored Session

Chair: Jamol Pender, Cornell University, Ithaca, NY, 14850, United States

**1 - New Perspectives on the Erlang-a Queue**

Andrew Daw, Cornell University, Jamol Pender

The non-stationary Erlang-A queue is a fundamental model used to describe the dynamic behavior of large scale multi-server service systems that experience customer abandonments, such as call centers, hospitals, and urban mobility systems. In this talk, we develop novel approximations for the moments, moment generating function, and cumulant generating function. We provide precise bounds for the difference of our approximations and the true model. Moreover, we show that our approximations have explicit stochastic representations as shifted Poisson random variables. Our approximations and bounds also hold for non-stationary Erlang-B and Erlang-C queues under certain stability conditions.

**2 - Asymptotic Methods for Queues with Delayed Information**

Sophia Novitzky, Cornell University, Ithaca, NY, United State

With the advancement of online technologies, services often provide waiting time or queue length information to customers. This information allows the customers to determine whether to remain in line or in the case of multiple lines, which line to join. Unfortunately, there is usually a delay associated with the waiting time information: either the information is not provided in real time or it takes the customers travel time to join the service after having received the information. Recent empirical and theoretical work uses functional dynamical systems as models for queueing systems and shows that if information is delayed long enough, a Hopf bifurcation can occur and cause unwanted oscillations in the queues. However, it is not known how large the oscillations are when a Hopf bifurcation occurs. To answer this question, we model queues with functional differential equations and implement two methods for approximating the amplitude of the oscillations. The first approximation is analytic and yields a closed-form approximation in terms of the model parameters. The second approximation uses a statistical technique, and delivers highly accurate approximations over a wider parameter range than does the first method.

**3 - The Impact of Smartphone App Information on****Bike Sharing Networks**

Shuang Tao, Cornell University, Ithaca, NY, United States

Many systems like Citibike and Divvy provide riders with information about the network via smartphone apps so that riders can find stations with available bikes. In this paper, we study the impact of the smartphone app and its power to guide riders to non-empty stations. By combining customer choice modeling and finite capacity queueing model, we prove a mean-field limit and a central limit theorem for an empirical process of the number of stations with  $k$  bikes. Our results illustrate that if we increase the proportion of customers that use smartphone app information, the entropy of the bike sharing network is reduced, the network has a higher throughput, and riders experience less blocking in the network.

**4 - The Impact of Queues with Delay and Pollution Announcements**

Jamol Pender, Cornell University, 228 Rhodes Hall, Ithaca, NY, 14850, United States

Travel time information has been estimated and provided to drivers to help them make better routing decisions and alleviate congestion. However, because of challenges in data collection and sensor delays, travel time information is often delayed and hence inaccurate. This can misguide drivers and result in unstable traffic patterns. To this end, we explore the potential of giving drivers real-time en-route air pollution information and we develop a new queueing model that considers the behavior of drivers provided with both travel time and air pollution information. Our results indicate that provision of real-time air pollution information to travelers may help stabilize traffic.

**■ TA40**

North Bldg 226B

**Expert Elicitation**

Sponsored: Decision Analysis

Sponsored Session

Chair: Erin Baker, Univ of Massachusetts-Amherst, Univ of Massachusetts-Amherst, Amherst, MA, 01003, United States

Co-Chair: Claire Cruickshank, Plano, TX, 75093, United States

**1 - An Anchoring Explanation of Over- and Under-confidence during Probability Elicitation**

Saurabh Bansal, Penn State University, 405 Business Building, State College, PA, 16801, United States

Understanding how good individuals are at estimating probability distributions is critical to theory and practice of decision analysis. A large body of literature has addressed this issue. The findings appear contradictory: some article report that decision makers' judgments exhibit overconfidence while some others report underconfidence. We reconcile these seemingly inconsistent findings by using an anchoring-and adjustment model. A series of laboratory studies confirm the theoretical development.

**2 - Combining Point Forecasts into a Predictive Distribution**

Zhi Chen, INSEAD, 1 Ayer Rajah Avenue, Singapore, 138676, Singapore, Anil Gaba

Experts provide forecasts for a variable of interest often in the form of point forecasts, i.e., single-valued predictions. However, a decision maker has to then take the additional step of converting the point forecasts into a predictive distribution for that variable, necessary for the decision at hand. Theoretical and practical issues on this additional step will be discussed, including accounting for dependence among the experts.

**3 - Does the Elicitation Mode Matter? Comparing Different Methods for Eliciting Expert Judgement**

Claire Cruickshank, MS. Student, University of Massachusetts, Amherst, MA, 01003, United States, Erin Baker

An expert elicitation is a method of eliciting subjective probability distributions over key parameters from experts. Traditionally an expert elicitation has taken the form of a face-to-face interview; however, interest in using online methods has been growing. Our research project compared online and face-to-face elicitations by examining the effect of elicitation mode on the central values, overconfidence, accuracy and satisficing. Our results indicated that, in instances where the elicitation modes were directly comparable, the differences between the modes was not significant. Consequently, a carefully designed online elicitation may be used to obtain accurate forecasts.

**4 - Aggregating Non-expert Opinions: Mechanism Design of Grading Scheme in MOOCs**

Steve Yoo, University College London, London, United Kingdom, Dongyuan Zhan

One issue of operating Massive Open Online Courses (MOOCs) is the scalability of grading. MOOCs resort to peer-grading system. We model student learning and grading efforts in two stages. We find that with proper incentive in peer-grading, students exert more efforts in grading, which motivate their learning. Our model presents empirically testable model for researchers, and objective metrics for MOOCs to tailor their grading mechanism for each course.

## ■ TA41

North Bldg 226C

### Decision Analysis, Game Theory, Big Data, and Homeland Security

Sponsored: Decision Analysis

Sponsored Session

Chair: Jun Zhuang, PhD, University at Buffalo, Buffalo, NY, 14260, United States

#### 1 - Concentrated vs. Distributed Defense as a Deterrent to Cyber Attackers: A Behavioral Analog Simulation Game

Richard S. John, University of Southern California, Dept of Psychology MC 1061, Los Angeles, CA, 90089-1061, United States, Sarah Kusumastuti, Heather Rosoff, James Blythe

Deterrence is an important component of cyber security that requires an understanding of attacker perceptions of success uncertainty. We developed an analog simulation game that offers attackers 4 different types of equally defended targets, including 3 with concentrated defenses at 1 of 3 different layers and 1 with a distributed (layered) defense. A total of 80 attackers played 36 rounds of the game in which the likelihood of success was held constant for all 4 target types. Compared to the distributed (layered) defense, attackers preferred to attack the concentrated defenses at the 2nd and 3rd layers, and were most deterred by the concentrated defense at the perimeter.

#### 2 - Optimal Standard of Human Rights in Countering an Insurgency: Theory and Empirical Analysis of AFSPA in India

Aniruddha Bagchi, Kennesaw State University, 1000 Chastain Road, MD 0403, Kennesaw, GA, 30144, United States, Jomon Paul

We explore why human rights violations take place in the midst of a rebellion. Our results indicate that faulty intelligence compels governments to tolerate human rights violations of its armed forces. We then examine the effect of a decrease in the human rights standard on the probability of quelling the rebellion. In our theoretical model, this effect is indeterminate (that is, can be positive or negative). We therefore empirically quantify this effect using the case of the Armed Forces Special Powers Act (AFSPA) in India. We find that a lowering of the standard of human rights reduces the chance of quelling the rebellion and this effect is statistically significant.

#### 3 - Denuclearization or Not? A Multiple-player Sequential , United StateGame Model

Jun Zhuang, University at Buffalo, Buffalo, NY, United States, Puyu Ye

The Democratic People's Republic of Korea (DPRK) nuclear crisis is a complex international issue. We use a multiple-player sequential game model to analyze the strategic interactions of these players. A multi-attribute (politics, economy, military) utility model is used for each player. The developed framework provides insights to decision making in this complex and important issue of denuclearization.

#### 4 - Does Learning from Past-disasters Make Future Disasters Costlier?: Insights from Fema's Public Assistance

Allison C. Reilly, Assistant Professor, University of Maryland, , 4298 Campus Dr., College Park, MD, 20742, United States, Hamed Ghaedi

The factors that explain rising costs of natural disasters are numerous: more intense hazards, more exposure in vulnerable places, and the lack of preparedness by residents. However, in the era of more frequent hazards, might disaster costs be rising because some individuals and organizations are simply learning how to more effectively apply for disaster aid? In this research, using statistical methods, we explore the propensity and ability of organizations to file for disaster aid based on their previous experience(s) filing for aid.

## ■ TA42

North Bldg 227A

### Teaching Simulation

Sponsored: Simulation

Sponsored Session

Chair: Laurel Travis, Virginia Tech

#### 1 - Adventures in Teaching Simulation: Virtual Reality, Vendor Competitions, and Real-world Projects in Very Large Classes

Laurel E. Travis, Virginia Tech, 3440 Cameo Lane, Blacksburg, VA, 24060, United States

We will discuss "tales from the field in teaching simulation within resource constraints. Specifically, 1) Introducing virtual reality into a discrete-event simulation course without any investment in equipment and only a small

investment of time, 2) Coaching a world champion team in the Simio student competition with limited faculty time, and 3) Managing semi open-ended applied projects with real-world clients in a class of nearly 200 students. Costs and benefits of these experiences will be discussed, with ideas on how to make them practical. Teaching materials will be distributed.

#### 2 - Survival Tips for Teaching Undergraduate Classes, Especially Simulation

Shane Henderson, Cornell University, School of ORIE 230 Rhodes Hall, Cornell University, Ithaca, NY, 14853, United States

I'll discuss my opinions on teaching undergraduate classes, with special emphasis on Monte Carlo and discrete-event simulation. The principles are mostly more general than just simulation, though. Key concepts include: If all else fails, be organized; No surprises; Design lectures like heartbeats; Avoid email; Take care with designing exams; One point wonders; Why is it true; Don't build models in class.

#### 3 - Teaching Undergraduate Simulation – What Works, What Doesn't

Jeffrey Smith, Auburn University, Industrial and Systems Engineering Dept, 3301 Shelby Center, Auburn University, AL, 36849-5346, United States

This talk focuses on teaching undergraduate simulation in an engineering department. The material is based on the experiences of doing this for 25 years and using several simulation tools and alternative textbooks and external resources. I'll focus on what has worked for me and what hasn't.

## ■ TA43

North Bldg 227B

### Energy and Climate III

Emerging Topic: Energy and Climate

Emerging Topic Session

Chair: Murat Erkok, University of Miami, Hialeah, FL, 33015, , United StateUnited States

#### 1 - A Multiobjective Model for Integrated Electricity and Natural Gas Pipeline Networks with Nonlinear Natural Gas Investment Cost

Ahmet Akgun, Wichita State University, Wichita, KS, 67226, United States, Mehmet Bayram Yildirim, Mehmet Barut

A multi-objective mathematical model for long-term integrated electricity and natural gas pipeline network is presented. The multiobjective model optimizes both electricity and natural gas networks simultaneously to determine the type of generation and transmission units, the location and capacity of these units. The nonlinear natural gas investment cost function is linearized by using PLA method.

#### 2 - Energy Policy Making with a Multi-objective Multi-perspective Game Theoretic Approach

Busra Keles, University of Miami, 1251 Memorial Drive, McArthur Engineering Building, Coral Gables, FL, 33146, United States, Murat Erkok, Nurcin Celik

Current energy policy solutions are struggling to overcome strategic decisions that involve a large number of stakeholders, sustainable actions of exploiting renewable energy sources, future capacity investments, and economical regulations. This paper addresses these issues and handles a energy policy making problem on the development and incentivization of energy policies. The problem is stated as a multi-objective (economic well-being, environmental protection, and energy surety) multi-perspective problem, and the solution framework is proposed in a game theoretic approach. Our approach overcomes the problem of valuation of conflicting objectives in an uncertain environment.

#### 3 - A Dynamic Data-driven Application Systems for Infosymbiotic Challenges of Solar-powered Microgrids

Haluk Damgacioglu, PhD. Candidate, University of Miami, Miami, FL, 33143, United States, Nurcin Celik

The integration of renewable energy sources and energy storage systems into microgrids premises energy resilience and independence for the communities. Yet, this integration, together with the uncertainties in the power supply and demand, makes the control of such microgrids quite challenging. Here, we present a preliminary dynamic-data-driven adaptive systems framework for the design and configuration of a solar-powered microgrid for a real world case study. Our approach shows promising results in terms of selecting the best available design using a tractable robust optimization model and a multi-fidelity microgrid simulation.

#### 4 - Detection and Attribution of Climate Change Using Offline Model Simulations for Streamflow in the Columbia River Basin

Mingzhou Jin, University of Tennessee-Knoxville, 525D John D. Tickle Engineering Building, Industrial and Systems Engineering, Knoxville, TN, 37996, United States, Whitney Forbes, Jiafu Mao

Detection and attribution analysis is the processes of statistically detecting a change in a particular climate variable or affected variables. Variables studied here are annual and seasonal in the Columbia River Basin for 1950 - 2008. The availability of a daily naturalized streamflow dataset and a new ensemble of semi-factorial land surface model simulations with less biased precipitation make the streamflow study for the basin more accurate. For forcings, the effects of climate change and variability, carbon dioxide concentration, nitrogen deposition, and land use and land cover change are used. Changes of the center of timing and seasonality were detected and attributed to climate changes.

#### ■ TA44

North Bldg 227C

#### Managing Uncertainty in Electric Power Networks

Sponsored: Energy, Natural Res & the Environment/Electricity  
Sponsored Session

Chair: Johanna L. Mathieu, University of Michigan, Ann Arbor, MI, 48109, United States

##### 1 - Data-driven Distributionally Robust Stochastic Optimal Power Flow

Tyler Summers, University of Texas Dallas, Dallas, TX, United States

We propose a data-based method to solve a multi-stage stochastic optimal power flow (OPF) problem based on limited information about forecast error distributions. Instead of assuming the uncertainties follow prescribed probability distributions, we consider ambiguity sets of distributions centered around a finite training dataset. By utilizing the Wasserstein metric to quantify differences between the empirical data-based distribution and the real unknown data-generating distribution, we formulate a multi-stage distributionally robust OPF problem to compute control policies that are robust to both forecast errors and sampling errors inherent in the dataset.

##### 2 - Statistical Ranking for Flexible Robust Unit Commitment

Lindsay Anderson, Cornell University, 316 Riley-Robb Hall, Ithaca, NY, 14853-5701, United States, Amandeep Gupta

With increasing scale, complexity, and variability in modern power systems, there is a benefit to combining statistical tools with analytical framework of power system methods to provide much needed flexibility to system operators. This work describes a statistical ranking methodology that allows for adaptive robust stochastic unit commitment using a modular and customizable structure. The method and its applications are illustrated via case studies performed on IEEE-30 bus and 118-bus test systems and compared to other established approaches. The ranking model is further implemented in a multi-objective framework to analyze performance with competing worst-case scenarios.

##### 3 - Operating Under Uncertainty in Smart Communities

Kyri Baker

Evolving energy systems are introducing heightened levels of uncertainty and stress on the electric grid. Increasing renewable generation, new market structures, and the proliferation of connected devices are transforming the operation of traditional energy systems, from the bulk grid to the operation of individual building components. To alleviate these issues, practical operational strategies which directly incorporate uncertainty need to be developed. This talk will introduce chance constrained and joint chance constrained optimization methods that aim to ensure operational guarantees in distribution networks and grid interactive buildings in future smart communities.

##### 4 - Distributionally Robust Chance Constrained Optimal Power Flow Assuming Log-concave Distributions

Bowen Li, University of Michigan, Ann Arbor, MI, United States, Ruiwei Jiang, Johanna Mathieu

Chance constrained (CC) optimization is widely used to solve the optimal power flow (OPF) problem under uncertainty but its solution can be affected by an inaccurate estimate of the underlying distribution. To obtain a robust solution, distributionally robust (DR) techniques are used by considering a set of distributions sharing the common properties rather than a single distribution. Here, we develop a new DRCC OPF formulation that incorporates moment, support, and log-concavity information. We then derive approximations based on second-order cone programs and evaluate the results on IEEE test cases.

##### 5 - Learning Demand Response Elasticity in Chance-constrained Optimal Power Flow

Yury Dvorkin, New York University, Metrotech Center, Fay Street, Brooklyn, NY, 11201, United States

The flexibility of demand response (DR) resources can be leveraged to accommodate the stochasticity of some distributed energy resources. This presentation will describe an approach to continuously learn time-variant price

elasticity of DR resources and integrate this updated knowledge in the chance-constrained optimal power flow framework. This integration is shown to adequately remunerate DR resources and efficiently co-optimize the dispatch of DR and conventional generation resources.

#### ■ TA45

North Bldg 228A

#### Sustainable Energy and Environmental Policy

Sponsored: Energy, Natural Res & the Environment/Electricity  
Sponsored Session

Chair: Makoto Tanaka, National Graduate Institute for Policy Studies (GRIPS), 7-22-1 Roppongi, Minato-ku, Tokyo, 106-8677, Japan

##### 1 - Regulatory Jurisdiction and Policy Coordination: A Bi-level Modeling Approach for Performance-based Policy

Makoto Tanaka, National Graduate Institute for Policy Studies (GRIPS), 7-22-1 Roppongi, Minato-ku, Tokyo, 106-8677, Japan, Yihsu Chen, Afzal Siddiqui

This study discusses important aspects of policy modeling based on a leader-follower game of policymakers. We specifically investigate non-cooperation between policymakers and the jurisdictional scope of regulation via bi-level programming. Performance-based environmental policy under the Clean Power Plan (CPP) in the U.S. is chosen for our analysis. We argue that integration of policymakers is welfare enhancing. Somewhat counterintuitively, full coordination among policymakers renders performance-based environmental policy redundant. We also find that distinct state-by-state regulation yields higher social welfare than broader regional regulation.

##### 2 - Market Power in Policy Mix: Cap-and-trade and Renewable Portfolio Standards

Mari Ito, Tokyo University of Science, Chiba, Japan, Ryuta Takashima

Policies for reducing greenhouse gas emissions, e.g., emissions permits trading as cap-and-trade (C&T), and renewable energy policy as renewable portfolio standards (RPS), have been introduced in various countries. In this work, we examine market equilibria under C&T and RPS mix in bi-level optimization framework. For the lower level, generation of outputs of renewable and non-renewable sectors and electricity prices are decided by maximizing sectors' profits. For the upper level, the policy maker chooses the rate of emission cap and the RPS requirement in an attempt to maximize the social welfare. Our results indicate that their policy mix is the best scheme for increasing social welfare.

##### 3 - Multiagent Simulation with Reinforcement Learning Agents for Integrative Evaluation of Renewable Energy Policies

Masaaki Suzuki, Tokyo University of Science, 2641 Yamazaki, Noda-shi, Chiba, Japan, Mari Ito, Ryuta Takashima

Even as governments combat greenhouse emissions through a range of initiatives, scholarship has yet to clarify how renewable energy policy, energy market structure, and number of energy producers impact social welfare. We model a deregulated market for electricity as a blind single-price call auction and construct a multi-agent system with reinforcement learning that facilitates more realistic market evaluations and observation of equilibrium processes. We validate our simulation by comparing its results with the results from theoretical analysis in a simplified market.

##### 4 - Investment in Power Generation and Transmission: The Effect of Capacity Size and Expansion

Kazuya Ito, National Graduate Institute for Policy Studies (GRIPS), Japan, Makoto Tanaka, Ryuta Takashima

The penetration of renewable energy has induced a decrease in capacity factors and a decommissioning for existing generations, and a reduction in new investments. This problem implies a fear for the shortage of capacity in the electricity market. Thus, in order to meet the capacity in the market, policymakers implement various policies for capacity procurement. In this work, we analyze investments in power generation and transmission by means of real options theory. The ISO decides the investment timing by maximizing social welfare whereas a power generator invests by maximizing the own profit. Especially, we examine the effect of capacity procurement for the ISO on the investment decisions.

##### 5 - Real Options in Renewable Portfolio Standards

Makoto Goto, Hokkaido University, Sapporo, Japan, Ryuta Takashima

In this paper, we examine a market equilibrium under uncertainty in RPS by means of real options analysis. More concretely, we analyze an investment timing for renewable producer. After that, we derive optimal RPS target. We have found results about the effect of uncertainty on market equilibrium and optimal RPS target. For fixed RPS target, high RPS target accelerates investment and decreases greenhouse gas. For the optimal RPS target, high RPS target disturbs innovation due to decrease in RE's revenue from REC market, and increases greenhouse gas due to investment delay. This is a new finding in this area.



## ■ TA46

North Bldg 228B

**Energy System Optimization**

Sponsored: Energy, Natural Res &amp; the Environment/Energy

Sponsored Session

Chair: Kai Pan, Hong Kong Polytechnic University, M507a, 5/F, Li Ka Shing Tower, Kowloon, Hong Kong

**1 - High Performance Computing Based Real-time Power System Contingency Analysis Considering Corrective Actions**

Yong Fu, PhD, Mississippi State University, Mississippi State, MS, 39762, United States

To achieve a high level of power system reliability, higher order contingencies should be included in the real-time system operation analysis. This presentation will discuss a high performance computing compatible comprehensive framework to enable real-time power system contingency analysis with consideration of various combinations of contingency events. The proposed approach ensures all decomposed subproblems scalable and tractable. In addition, the proposed approach is implemented on the high performance computing platform that significantly reduces the computation time to meet real-time operation requirements while improving the power system operation to a higher level.

**2 - Demand Response in Data Centers via Integration of Server Provisioning and Power Procurement**

Soongeol Kwon, Binghamton University, SUNY, 4400 Vestal Pkwy E, Systems Science and Industrial Engineering, Binghamton, NY, 13902, United States

Data centers consume a phenomenal amount of energy that contributes to huge energy costs and CO2 emissions. Thus, data centers have been striving to improve energy-efficiency, meet power demand load in response to the time of use rate, and utilize clean renewable energy. This study is motivated by the unique opportunity to improve the current practice by facilitating demand response based on the co-optimization of server operations and power procurement. The main objective of this study is to develop a decision-making model for applying demand response to data centers, and this study evaluates the quantitative benefits of the proposed model through numerical experiments using real historical data.

**3 - Co-optimizing Energy and Ancillary Services**

Kai Pan, Hong Kong Polytechnic University, M507a, 5/F, Li Ka Shing Tower, Kowloon, Hong Kong, Jianqiu Huang, Yongpei Guan

To ensure system reliability, ancillary services are introduced for power system operations to reserve excess generation capacities so as to accommodate uncertainties. In this paper, we develop an optimization model for system operators to efficiently schedule the generation assets, so as to jointly optimize power generation and ancillary services.

**4 - A Fully-distributed Asynchronous Approach for Multi-area Coordinated Network-constrained Unit Commitment**

Lei Wu, Clarkson University, 8 Clarkson Avenue, P.O. Box 5720, Potsdam, NY, 13676, United States

A consensus-based alternating direction method of multipliers (ADMM) approach is discussed to solve the multi-area coordinated network-constrained unit commitment (NCUC) in a distributed manner, including: (i) A tie-line power flow based area coordination strategy is designed to reduce global consensus variables; (ii) Different penalty parameters are assigned to individual consensus variables and are updated via certain rules during the iterative procedure; (iii) Heuristic rules are adopted to fix certain unit commitment variables for avoiding oscillations; and (iv) An asynchronous distributed strategy is studied.

## ■ TA47

North Bldg 229A

**Optimization Modeling and Techniques for Systemic Risk Assessment and Control in Financial Networks**

Emerging Topic Session

Chair: Douglas Shier, Clemson University, Dept Mathematical Sciences, Clemson, SC, 29634-0975, United States

**1 - Optimization Modeling and Techniques for Systemic Risk Assessment and Control in Financial Networks**

John R. Birge, University of Chicago, Booth School of Business, 5807 South Woodlawn Avenue, Chicago, IL, 60637, United States, Jiming Peng, Aein Khabazian

Since the crisis in 2007-2008, the assessment and control of systemic risk in financial networks has become one of the most important and active research areas in economics and finance. In this tutorial, we give a basic introduction to various optimization models including linear optimization problems (LO) with

uncertain data, linear optimization with non-convex quadratic constraints (QCLO), mixed integer linear optimization (MILO), and stochastic optimization that arise from the following three topics in the risk analysis of financial networks: (i) vulnerability analysis; (ii) identification of the least stable network structure; (iii) risk mitigation.

## ■ TA48

North Bldg 229B

**Supply Chain Information Disclosure Workshop**

Sponsored: Energy, Natural Res &amp; the Environment Environment &amp; Sustainability

Sponsored Session

Chair: Donna Marshall, University College-Dublin, Dublin, Ireland

Co-Chair: Steve New, University of Oxford, United Kingdom

**1 - Untangling Sustainability - Comparing Processes for Social and Environmental Performance at Chinese Suppliers**

Veronica H. Villena, Penn State University, 412 Business Building, Supply Chain and Information Systems, State College, PA, 16802, United States, Miriam Wilhelm, Cheng Yong Xiao

We use a multi-method approach to untangle the drivers of environmental and social sustainability. We first conducted a case study with nine Chinese suppliers and then analyzed longitudinal data for 145 Chinese suppliers in the 2013-2017 period. Our study offers a systematic comparison between the environmental and social sustainability and reveals the drivers for each dimension of sustainability.

**2 - Blockchain Research in Supply Chain Management: A Structured Literature Review**

David Swanson, University of North Florida, Jacksonville, FL, United States, Dawn Russell, Jin Yao, Kristoffer Francisco

This research provides results from a systematic literature review on blockchain literature in supply chain management from January 2015 through August 2018. Research articles are coded by theories used, journal, author, discipline, subject, methodology, and other criteria. Information is tabularized and graphed to ease interpretation. The tables are presented so that researchers can use the information for their own research into supply chain applications of blockchain. Conclusions and implications for academia and practice are drawn from the data.

**3 - Reveal the Supplier List? A Trade-off in Capacity vs. Responsibility**

Kalkanci Basak, Georgia Institute of Technology, Atlanta, GA, United States, Erica Plambeck

Some buying firms, facing scrutiny regarding social and environmental violations in their suppliers' operations, have recently made commitments to publish the identities of their current and/or terminated suppliers. In this paper, we study the trade-offs faced by a buying firm in deciding whether or not to make such transparency commitments. We identify the conditions under which a buying firm should commit to publish its supplier list, and the conditions under which the buying firm should make complementary investments to help the supplier become more productive.

**4 - A Longitudinal Investigation of Supply Chain Information Disclosure in the Electronic Industry: The Case of Hewlett Packard**

Uche Okongwu, Professor of Supply Chain Management, Toulouse Business School, 20 Boulevard Lascrosses, Toulouse, 31000, France

It has been reported in the literature that disclosure requirements are transitioning from voluntary to mandatory as sustainability reporting becomes required by regulators and stakeholders. Therefore, some research is needed to investigate the extent as well as the speed at which companies are gaining maturity in disclosing sustainability information. By conducting a longitudinal study, this paper looks at the evolution of supply chain sustainability information disclosed by Hewlett Packard, a leading electronic company. To carry out this study, we used a framework that takes into consideration three components: the category, the nature and the measurability of the information disclosed.

**5 - Drivers and Outcomes of Supply Chain Information Disclosure**

Donna Marshall, University College Dublin, Carysfort Road, Dublin, Ireland, Lucy McCarthy, Paul McGrath

This study shows the development of a theory of supply chain information disclosure. We develop 16 cases from fashion, electronics, medical devices and pharmaceuticals in order to build a model of supply chain information disclosure and understand the drivers, barriers and outcomes of disclosure across the four industries and within the industries and cases.

## ■ TA49

North Bldg 230

**Joint Session SOLA/ENRE: Resource Management in**

## Supply Chain and Facility Location

Sponsored: Energy, Natural Res & the Environment Environment & Sustainability

Sponsored Session

Chair: Yihsu Chen

### 1 - Issues and Challenges for Closed Loop Supply Chain Considering of Commodity Value and QCDE

Aya Ishigaki, Tokyo University of Science, Tokyo, Japan,  
Tetsuo Yamada, Ryuta Takashima

In recent years, it is known that the environmental impact by the product quality in manufacture and recovery phase and the energy mix (coal, natural gas, nuclear energy, etc.) of electric power changes with selections of the producing countries or the consuming countries. Furthermore, it is necessary to design and manage a supply chain, considering not only the current value of a product or parts but future value. This study discusses about an issue of closed loop supply chain considering commodity value and QCDE (quality, cost, delivery, and environment).

### 2 - A Mathematical Model for Real-time Pricing of Electricity to Control Supply and Demand in a Smart Community

Mihiro Sasaki, Nanzan University, 18 Yamazato, Showa, Nagoya, 466-8673, Japan

We consider a smart community consisting of smart houses in which each is equipped with a fuel cell (FC) system, a photovoltaic (PV) system and a power storage. The supplier of electricity (CEMS: Community Energy Management System) presents the electricity price varying with different time, and customers living in smart houses (HEMS: Home Energy Management System) determine their own optimal levels of buying/selling electricity in responding to the time-varying price. We formulate a problem of finding optimal pricing on the condition that each HEMS finds an optimal schedule to minimize its own total cost as a bilevel programming problem.

### 3 - Analysis for Maritime Transportation of Energy Resources using AIS Data

Shigeki Toriumi, Chuo University, 1-23-27 Kasuga, Bunkyo-ku, Tokyo, 112-8551, Japan, Yihsu Chen

In this research, we analyze maritime transportation of energy resources using "Automatic Identification System (AIS)" data. The AIS is an automatic tracking system used on ships. Using this data, we can identify each voyage which include origin, destination, route and speed, so on. Furthermore we can produce an animation which represents vessel movement in the world. We evaluate economic efficiency and risk for transportation of energy resources by comparing with our previous research.

### 4 - Multi-product Pickup and Delivery Supply Chain Design with Cross Dock Location and Direct Shipment

Vahid Azizi, Iowa State University, Ames, IA, United States,  
Guiping Hu

The cross docking process is important in supply chain management. Cross docking makes the material flow more efficient and reduces transportation and inventory holding costs and accelerates delivery. Although important, the decisions of locating cross-docks are considered separately from shipment routing. This paper presents a model that considers cross-dock location, pickup and delivery vehicle routing, and direct shipment together with cross docking. A mixed integer linear programming model has been formulated to address this problem. Computational experiments have been conducted to validate the proposed model.

## TA50

North Bldg 231A

## Healthcare/Service Systems in Applied Probability

Sponsored: Applied Probability

Sponsored Session

Chair: Lerzan E. Ormeci, Koc University, Rumeli Feneri Yolu, Sariyer, Istanbul, 34450, Turkey

### 1 - Optimal Control Policies in Systems that Include Batch Characteristics

Olga Bountali, Southern Methodist University, 4210 Fairmount Street, Apartment 3063, Dallas, TX, 75219, United States,  
Lerzan E. Ormeci

The control of a service system of interest becomes very complicated when the system operates under some notion of batches. The latter, regardless of whether it refers to the arrival or service patterns, creates intricate trade-offs, the resulting impact of whose can be either detrimental or beneficial. We shed more light to this impact by exploring optimal control policies for systems that operate under some notion of batches.

### 2 - Analysis of a Healthcare System Consisting of Public and Private Facilities

Seyedehsaloumeh Sadeghzadeh, Virginia Tech, Blacksburg, VA, 24060, United States, Lerzan E. Ormeci, Pelin Canbolat

We consider a setting where a healthcare service is provided by two facilities, one public, and one private. Each facility is represented by an M/M/1 queue with different service rates and fees. Customers strategically choose one of the two facilities to minimize their expected cost, which consists of waiting costs and fees, under two different conditions corresponding to observable and unobservable queues. We also analyze socially optimal policies under these conditions. We characterize key structural properties in each case, and consider how the government can use these results to decide on the compensation level for private services, and the investment on capacity expansion in public services.

### 3 - Admission Control in an Intensive Care Unit with Readmissions

Faruk Akin, Rumelifeneri Mah., Rumelifeneri Yolu, Sariyer, Istanbul, 34450, Turkey, Koc University, Koc University, Rumelifeneri Mah. Rumelifeneri Yolu, Sariyer, Istanbul, 34450, Turkey, Lerzan E. Ormeci

We consider an Intensive Care Unit (ICU) where we focus on the effects of early discharge decisions and possible readmissions on hospital bed management. The system may admit, reject or admit an arriving patient by early discharging a current patient in the ICU. To represent such a setting, we develop a discrete-time Markov Decision Process (MDP) with the aim of minimizing the total expected - discounted cost over an infinite horizon. We investigate the structure of the optimal admission control policy and propose some heuristic policies and evaluate their performances with respect to the optimal policy, which results from solving the MDP formulation.

## TA51

North Bldg 231B

## Joint Session OMS/Practice Curated: Scheduling with Applications

Emerging Topic: Project Management and Scheduling, in Memory of Joe Leung,

Emerging Topic Session

Chair: Marc E. Posner, Ohio State University, 296 Baker Systems Engineering, 1971 Neil Avenue, Columbus, OH, 43210-1271, United States

### 1 - AGV Control in Large-scale Parallel Transshipment Container Terminal

Qitong Zhao, National University of Singapore, Singapore, Chenhao Zhou, Lee Loo Hay

The AGV system in transshipment container terminal is characterized by a very large number of AGVs and complicated traffic conditions. To ensure deadlock- and conflict-free routing of the AGVs, we propose a modular concept, allowing the AGV control to be divided into two subproblems, the travel module generation problem and the inner module routing and scheduling problem. These two subproblems are integrated and tested in our discrete event simulation platform. Visualization of the solutions validate the deadlock- and conflict-free movements and numerical results show the efficiency of this two-stage event-trigger approach.

### 2 - AGV Routing in the Parallel Mega Automated Container Terminal Based on a Two-layer Network Structure

Chew Ek Peng, National University of Singapore, Computing Lab, E1-07-26, NUS Department of Eng, Singapore, 117578, Singapore, Zhipeng Qiu

To avoid conflicts and improve system efficiency in the mega-ACT, we propose an efficient routing scheme for large-scale AGVs based on a two-layer network structure. At the upper layer, a column-generation based algorithm is used in a sector-based graph for an integrated problem, which not only solve the path direction design to determine the directions for the links, but also solve the global routing to decide the sector-based routes for the AGVs. At the lower layer, a path planning algorithm is proposed for multi-AGVs within the sector to determine the real-time paths and schedules for AGVs with the guarantee of no conflicts. Finally, this study has used different cases for algorithm testing, and the results show that the scheme is efficient and effective for the routing of large-scale AGV systems.

### 3 - A New Approximation Algorithm for Unrelated Parallel Machine Scheduling Problem with Release Dates

Ziteng Wang, Assistant Professor, Northern Illinois University, 590 Garden Road, EB 240, DeKalb, IL, 60115, United States, Zhi Pei, Mingzhong Wan

We consider the unrelated parallel machine scheduling problem with release dates. A 4-approximation algorithm is devised and proved in comparison with the 16/3-approximation. The original scheduling problem is divided into several sub-problems based on the release dates. For each sub-problem, a convex quadratic

integer programming model is constructed in accordance with the specific problem structure. Then a semi-definite programming approach is implemented to produce a lower bound via the semi-definite relaxation of each sub-problem. Furthermore, a branch and bound based method and a local search strategy are applied separately to locate the integer solution of each sub-problem.

#### 4 - Approximation Algorithms for Stochastic Scheduling Problems with Few Different Types of Jobs

Lin Chen, University of Houston, 4800 Calhoun Road, Houston, TX, 77004, United States, Lei Xu, Weidong Shi

We consider the classical stochastic identical machine scheduling problem with the objective of minimizing weighted completion time. We show that there exists a quasi-polynomial time approximation scheme if there are a logarithmic number of different kinds of jobs.

## ■ TA52

North Bldg 231C

### Joint Session SMA/Practice Curated: Social Media Analytics Methods, Tools and Platforms

Emerging Topic: Social Media Analytics

Emerging Topic Session

Chair: Tung Cu, Bloomsburg University of Pennsylvania, 400 E. 2nd Street, Bloomsburg, PA, 17815, United States

#### 1 - Does Emotional Arousal Boost or Discount Review Valence Impact? The Role of Purchase Stage

Anh Dang, Northern Kentucky University, Haile/US Bank College of Business, Highland Heights, KY, 41076, United States, Yuping Liu-Thompkins

Conflicting findings exist regarding the impact of review valence on consumers' decisions. The present paper aims to reconcile these findings by examining emotional arousal expressed in review texts as a moderator of review valence impact. Through two experiments and one field study involving clickstream and purchase data of a major UK online retailer, this paper shows that emotional arousal plays two opposing roles depending on which decision stage the consumer is at. During the search stage, it prevents consumers from relying on valence. Meanwhile, when consumers are about to make their purchase decision, negativity bias causes consumers to reject products with negatively high arousal reviews.

#### 2 - Social Media Network Analytics: Methods, Tools and Platforms

Tung Cu, Bloomsburg University of Pennsylvania, 932 Country Club Dr., Bloomsburg, PA, 17815, United States

Social networking media is built on the ideological and technological foundations of web and mobile, and that allow the creation and exchange of user generated content. Research in social media analytics focuses on innovative methods and practices of measuring, analyzing and interpreting user-generated content from a variety of online social media platforms, websites, and blogs to uncover hidden patterns and correlations to answer questions pertaining to organizational, educational, social as well as political issues. This paper presents a literature review in both theoretical and empirical variety of social network analytics methods, tools and platforms in different contexts.

#### 3 - Social Analytics Governance: A Literate Review of Practices

Tung Cu, Bloomsburg University of Pennsylvania, 932 Country Club Dr., Bloomsburg, PA, 17815, United States, Loreen Powell, Ken Hall, Kuo- Hao Lee, Hayden Wimmer

Over the last ten years, the number of businesses harnessing structured, semi-structured or unstructured data have exploded. Today, many businesses are quick to view social analytic data as evidence or arguments. Oftentimes, the evidence and arguments leads to faulty decisions and lost profit because their data are not properly managed and governed. Thus, a business' ability to deliver accurate analytics is essential to be built on the capabilities of its data and technology governance and practices. Given the increased importance in data governance, this presentation presents a literature review and highlights areas for future research.

## ■ TA53

North Bldg 232A

### Procurement Design

Sponsored: Auction and Marketing Design

Sponsored Session

Chair: Vitali Gretschko

#### 1 - Sequential Procurement without Commitment

Vitali Gretschko, Centre for European Economic Research, 68034 Mannheim, Mannheim, Germany, Nicolas Fugger, Martin Pollich

Renegotiation of contracts is anticipated by the suppliers and in turn influences

the initial procurement mechanism. We show that first-price auctions may perform poorly in this context as all cost-types may pool on high bids to conceal relevant information for the renegotiation. Second-price auctions in such a setting should retain its efficient equilibrium as the buyer merely learns that the cost of the winning supplier is lower than some threshold. Moreover we derive the optimal mechanism.

#### 2 - First-price Auction Design with Loss Averse Bidders

Nicolas Fugger, Centre for European Economic Research (ZEW), L7, 1, Mannheim, 68161, Germany, Philippe Gillen, Tobias Riehm

Loss aversion describes that subjects evaluate outcomes relative to reference points and suffer more from negative deviations (losses) than they benefit from positive deviations (gains) from reference points. As a consequence, the outcome equivalence of first-price auction formats breaks down. We show that an auction designer who faces loss averse bidders can increase her profit above that attainable with standard first-price auctions by implementing a multi-stage first-price auction which consists of a qualification stage and a final.

#### 3 - Supplier Scorecards in Competitive Sourcing

Elena Katok, University of Texas at Dallas, 800 W. Campbell Rd., Jindal School of Management (SM30), Richardson, TX, 75080, United States, Zhixi Wan, Sina Shokoohyar

In procurement interactions, the relationship between the buyer and the seller starts after the sourcing decision has been made. In this study we consider ways to design a scorecard to best incentivize the suppliers.

#### 4 - A Theoretical and Experimental Study of Open-bid Auctions Under Post-qualification Screening

Wen Zhang, University of Texas at Dallas, 800 W. Campbell Road, Richardson, TX, 75080, United States, Elena Katok, Qi Chen, Zhixi Wan

We study a procurement setting in which one qualified supplier (the incumbent) and multiple unqualified suppliers (the entrants) compete in an open-bid auction under post-qualification. We find that the incumbent follows a bid-down-to thresholds strategy in which the incumbent should stay in the auction until the auction price reaches a threshold. Our analysis also shows that after the incumbent drops out, all entrants will follow a similar strategy, but one entrant's thresholds can only be calculated sequentially after reviewing the last drop-out bids. We test our analytical results in the laboratory with human subjects and explain mismatches between experimental observations and theories.

## ■ TA54

North Bldg 232B

### Behavioral Research on Sustainability and Environmental Operations

Sponsored: Behavioral Operations Management

Sponsored Session

Chair: Enno Siemsen, University of Wisconsin-Madison, Madison, WI, 53706, United States

Co-Chair: Mahdi Mahmoudzadeh, Georgia Institute of Technology, Atlanta, 30308, Georgia

#### 1 - Reliably Responsible: Structuring Supply Chains for Socially-responsible Behavior

Mahdi Mahmoudzadeh, Georgia Institute of Technology, Scheller College of Business, 800 West Peachtree Street NW, Atlanta, 30308, Georgia, Enno Siemsen

Social/environmental benefits of responsible sourcing in supply chains is well discussed in the literature and among practitioners. We extend the classical model of responsible sourcing with a behavioral decision-making process (BDM) for the manufacturer that sources from responsible and non-responsible suppliers. The BDM resolves some of inconsistencies in the classical model's predictions that limit providing straightforward recommendations. We validate our proposed BDM, against the classical decision-making, through incentivized experiments. The primary advantage of BDM is realized by structuring supply chains for different types of socially-responsible behavior in the market.

#### 2 - How Does Precision Affect the Adoption of Energy Efficiency Practices? - Evidence from the Field and Laboratory Data

Suresh Muthulingam, The Pennsylvania State University, Smeal College of Business, 460 Business Building, University Park, PA, 16802, United States, Saurabh Bansal

We investigate whether precision affects the adoption or non-adoption of energy efficiency practices. Specifically, we examine if the implementation of energy efficiency practices depends on whether the costs and savings associated with such practices are presented as precise (e.g., \$20,431) or round (e.g., \$20,400) numbers. Our empirical analysis and experimental results show that adoption rates are higher for those recommendations that have precise costs and precise savings. Additionally, the experiments demonstrate that such recommendations induce higher credibility with decision makers.



### 3 - The Effect of Visibility on Consumer Trust of Social Responsibility Disclosures

Leon Valdes, University of Pittsburgh, Joseph M. Katz Graduate School of Business, 119B Mervis Hall, Pittsburgh, PA, 15260, United States, Tim Kraft, Yanchong Zheng

We conduct an incentivized lab experiment to investigate the role of supply chain visibility on consumer trust of social responsibility (SR) communications. Specifically, we design a three-player game with the roles of Consumer, Seller, and Worker. The Worker's payment is private information, but the Seller observes a signal about this payment. The Seller can invest to improve this signal's quality, which captures the level of supply chain visibility. Finally, the Seller communicates with the Consumer about the observed signal. With this game, we study whether the level of visibility affects the Consumer's trust in the Seller's communication.

## ■ TA55

North Bldg 232C

### Joint Session Sports/Practice Curated: Sports Analytics IV

Sponsored: SpORts

Sponsored Session

Chair: Stephen Hill, University of North Carolina-Wilmington, 601 South College Road, Wilmington, NC, 28403-5611, United States

#### 1 - Optimizing Pitcher Rotations

Cody O'Brien, Slippery Rock University, Slippery Rock, PA, 16057, United States, Bradely Schweitzer, Justin Long

Replacing a starting pitcher with a relief pitcher is rarely backed by analytics. By taking an analytical approach, a manager may be able to detect when a pitcher's performance is starting to decline before it has a negative impact. Historical data is used to calculate multiple indicators of pitcher performance to create a baseline of how each individual pitcher should perform. During a game, current indicators will be calculated and compared to the baseline statistics to understand how the pitcher is performing. When his performance declines passed a set threshold, a relief pitcher will be called in. A fully-functioning GUI is implemented to make the model more accessible.

#### 2 - Simulating Major League Baseball Games

Brad Schweitzer, Slippery Rock University, Slippery Rock, PA, United States, Justin Long

The game of baseball can be explained as a Markov Process, as each state is independent of all states except the one immediately prior. Probabilities are calculated from historical data on every state transition from 2011 to 2016 for Major League Baseball games and are then grouped to account for home-field advantage, offensive player ability, and pitcher performance. Using the probabilities, transition matrices are developed and then used to simulate a game play-by-play. For a specific game, the results give the probability of a win as well as expected runs for each team.

#### 3 - Examination of Gambling Lines in College Football

Mikhail Gordon, Doctoral Candidate, University of Pittsburgh, Pittsburgh, PA, 15224, United States

An investigation of college football team characteristics in the context of gambling, using historical line information. An emphasis is placed on games with large spreads, defined as a spread greater than 15 points.

#### 4 - Social Network Analysis in Field Sports: Irish (Gaelic) Football

Vincent Hargaden, Associate Professor, University College Dublin, School of Mechanical & Materials Engineering, Engineering & Materials Science Centre, Belfield, Dublin 4, Ireland

Irish (Gaelic) football is a 15-a-side field sport played through a combination of hand and foot passing. Each year from May through September, the elite teams complete in conference and play-off games to determine the title winner. Similar to many team sports (basketball, soccer), it is of interest to analyse the players' cooperation from a network perspective. Using passing data between players from games involving the three-in-a-row title winning team (2015-2017), we take a social network analysis approach to identify interactions and team style of play.

## ■ TA56

West Bldg 101A

### Joint Session HAS/Practice Curated: Behavioral Drivers for Decision Making and Productivity: Empirical Evidence

Sponsored: Health Applications

Sponsored Session

Chair: Jónas Oddur Jónasson

#### 1 - Task Selection and Workload

Bradley R. Staats, University of North Carolina at Chapel Hill, Campus Box 3490, McColl 4720, Chapel Hill, NC, 27599-3490, United States, Diwas S. KC

How individuals manage their tasks is central to operations. Recent research focuses on how increasing workload individuals can increase service time. As the number of tasks increases workers may also manage their workload by a different process - task selection. We theorize and test that under conditions of increased workload individuals may choose to complete easier tasks to manage their load. We label this behavior Task Completion Bias (TCB). Using 2 years of data from an emergency department we find support for TCB and show it improves short-term productivity. However, we find that an overreliance on this task selection strategy hurts performance in the long run.

#### 2 - Heuristic Thinking in Patient Care

Diwas S. Kc, Emory University, 1300 Clifton Road, Goizueta Business School, Atlanta, GA, 30322, United States

This paper studies heuristic thinking and cognitive bias using a natural experiment from the field. The setting for the study is a set of acute care hospitals, where we examine the care process and discharge decisions for individual patients. Determining a patient's suitability for discharge is cognitively taxing, calling for the decision maker to draw on up-to-date clinical expertise and detailed information. We postulate that bounded rationality in decision making leads the care provider to substitute clinical readiness for discharge - a more cognitively complex attribute, with a more easily accessible heuristic.

#### 3 - Recovering from Distress: The Impact of Critical Incidents on Operational Performance

Jonas Oddur Jonasson, Assistant Professor, MIT Sloan School of Management, 30 Memorial Drive, E62-588, Cambridge, MA, 02142, United States, Hessam Bavafa

In service operations settings, where the difficulty of jobs can be unpredictable, workers sometimes encounter critical incidents (CIs) — tasks or situations which are sufficiently disturbing to challenge workers' usual coping mechanisms. In the context of ambulance services we find that encountering a CI negatively affects subsequent operational performance. The effect is strong for patient-pickup (a complex, non-standardized task) and weaker for patient handover to the hospital (a more standardized task).

#### 4 - Timeliness and Compliance with Standard Operating Procedures

Reidar Hagtvedt, University of Alberta School of Business, 2-43 Business Bldg, Edmonton, AB, T6G 2R6, Canada, Kenneth L. Schultz, Trish Reay, Sarah Forgeie

Compliance with standard operating procedures when looking ahead, or in the very short term, is notoriously difficult to measure. In this paper, we examine two previously ignored aspects of compliance with hand-hygiene regulations in a hospital setting. First, we allow teleological cues to prompt hand-hygiene by recoding the time of the cue forward. Second, we examine the time immediately after a disruption, to see if a reduction in hand-hygiene is measurable. We use data from a tertiary Canadian teaching hospital.

## ■ TA57

West Bldg 101B

### Joint Session HAS/Practice Curated: Dynamic Models of Patient Health

Sponsored: Health Applications

Sponsored Session

Chair: Maria Esther Mayorga, North Carolina State University, Raleigh, NC, 27695, United States

#### 1 - Dynamic Patient Routing with Nurse Workload Considerations

Siddhartha Nambiar, North Carolina State University, Raleigh, NC, 27606, United States, Maria Esther Mayorga, Muge Capan

We develop a multi-class, multi-server queueing model to route incoming patients to different server pools in an Emergency Department setting, to minimize their sojourn time and to manage the nurses' workload. There is a lack of consensus in analytics and decision science regarding how to quantify workload in healthcare and how to use it in an analytic framework. We first review literature to determine how to define workload, and to identify components, available in electronic health records data, that allow us to measure workload. Following this, we develop both analytic and simulation models to get optimal routing policies and compare them to other workable, realistic policies.

## 2 - Cost-effectiveness and Decision Analysis of Genetic Testing in Cholesterol Treatment Planning

Wesley J. Marrero, University of Michigan, Ann Arbor, MI, United States, Mariel Sofia Lavieri, Rodney A. Hayward, Suzanne C. Butler, Amit Khera, Sekar Kathiresan, James Burke, Jeremy B. Sussman

We present a simulation-based framework to estimate the risk of heart attacks due to clinical and genetic factors. Additionally, we develop cholesterol treatment plans using risk thresholds (current practice) and a Markov decision process (MDP). By simulating the health status of patients, we determined the cost-effectiveness of genetic testing to guide cholesterol treatment.

## 3 - Statin Initiation Decision Modeling for Prediabetes Patients

Shengfan Zhang, University of Arkansas, 4207 Bell Engineering Center, Department of Industrial Engineering, Fayetteville, AR, 72701, United States, Muhenned Abdulsahib

While there is much research on statin initiation policies on prevention of heart disease for diabetes, studies on statin initiation policies for prediabetic patients are limited. The goal of this research is to examine the tradeoffs between the risk of heart disease and risk of diabetes on the decision of statin therapy for prediabetes patients. We develop an optimal statin initiation policy to meet both the need to control cholesterol levels and the need to minimize the risk of diabetes, which will provide insights for future treatment guidelines for prediabetes.

## 4 - Modeling Comprehensive Medication Reviews for Complex Patients in Community Pharmacies

Kathryn N. Smith, North Carolina State University, Raleigh, NC, 27606, United States, Julie Simmons Ivy, Anita Vila-Parrish

Adherence to long-term medication therapies is approximately 50% in developed countries. Patient and provider engagement has been found to be a contributor to improved adherence. One enhanced service aimed at engaging patients is a comprehensive medication review (CMR) provided by pharmacists. CMRs allow a pharmacist to identify drug therapy problems that may be interfering with adherence. In order to incorporate CMRs into the workflow, pharmacies must streamline the CMR process and prioritize complex patients. We developed a simulation model and a dynamic programming model to analyze the integration of the operational and clinical workflows and determine how to prioritize patients.

## ■ TA59

West Bldg 101C

## Joint Session HAS/Practice Curated: Healthcare Analytics II

Sponsored: Health Applications

Sponsored Session

Chair: Pinar Keskinocak, Georgia Institute of Technology, Atlanta, GA, 30332, United States

Co-Chair: Seyma Guven-Kocak, Georgia Institute of Technology, Atlanta, GA, 30340, United States

## 1 - One-class Adaptive Resonance for Radiotherapy Quality Assurance

Dionne Aleman, University of Toronto, 5 King's College Road, Toronto, ON, M5S 3G8, Canada, Hootan Kamran Habibkhani, Chris McIntosh, Thomas Purdie

Radiotherapy (RT) treatment plans, once designed, must undergo iterative refinements until they pass quality assurance (QA). Machine learning has promised to help automate such QA processes by learning from past data. However, RT plans are usually not recorded until they passed QA and are sent for delivery. Therefore, a clinically-recorded RT dataset is usually imbalanced in favour of the easily-recordable high-quality plans, and binary classifiers struggle to learn from it. Therefore, we develop an adaptive neural network for one-class classification. Our algorithm outperforms one-class SVMs and autoencoders on two RT datasets for breast and prostate patients.

## 2 - Updating Risk Assessment Tools for Unplanned Extubation in Pediatric Critical Care Patients

Zihao Li, Georgia Institute of Technology, Atlanta, GA, United States, Pinar Keskinocak, Atul Vats

The Risk assessment score (RAS) and revised RAS (rRAS) are scoring tools based on consensus opinion to assess pediatric patients' risk of unplanned extubation (UPE). We reviewed records of 5,749 patients from 2013 to 2017 in 5 ICUs and 2 freestanding children's hospitals and used logistic regression to improve the score. The new model identifies UPE history, weight, age, oral secretion and ventilation length as significant risk factors. The incident rates for low, moderate, high, and extreme risk patients are 0.69, 0.46, 1.14 and 3.01 per 100 vent days, respectively. The new model has a stronger association with UPE occurrence for patients with extreme risk compared to the RAS and rRAS.

## 3 - Calling for Care? The Risky Proposition of Teletriage for Healthcare Demand Management

Ozden Engin Cakici, American University, Washington, DC, United States, Alex Mills

We investigate the effect of adding teletriage to a healthcare system with traditional or open access primary care and an Emergency Department (ED). Using a partially observable Markov decision process model, we find that while teletriage would benefit patients, it could be costly for the payer and even increase ED usage. We conclude by providing conditions under which teletriage would be beneficial.

## 4 - Dynamic Personalized Patient Classification via Learning Progression in Chronic Diseases: Application to Glaucoma

Esmaeil Keyvanshokoo, University of Michigan, Ann Arbor, Ann Arbor, MI, 48108-1020, United States, Mark P. Van Oyen, Joshua Stein, Mariel Sofia Lavieri, Chris Andrews

We design a dynamic and personalized classification method for classifying a patient with Glaucoma at each visit as either a "fast" or "controlled" progressor. "Fast" refers to relatively rapid deterioration with respect to visual field mean deviation. To this aim, we combine a random forest algorithm with a classification method. We also develop online learning methods to help manage a patient's progression.

## ■ TA59

West Bldg 102A

## Joint Session HAS/DM: Aged Care Analytics: Models, Methods and Applications: Part I

Sponsored: Health Applications

Sponsored Session

Chair: Mingyang Li, Tampa, FL, 33647, United States

Co-Chair: Nan Kong, Purdue University, West Lafayette, IN, 47906-2032, United States

## 1 - Skilled Nursing Facility Service Utilization Modeling and Staffing Evaluation with Competing Discharge Disposition

Nazmus Sakib, University of South Florida, Tampa, FL, United States, Xuxue Sun, Nan Kong, Chris Masterson, Hongdao Meng, Kathryn Hyer, Mingyang Li

Skilled nursing facilities (SNFs) are major long-term care settings for older adults. It is important to accurately model SNF service demands so that an appropriate staffing level can be determined to ensure high quality care at a reduced cost. This work proposes a data analytics integrated simulation framework to evaluate the service demands of SNF residents and further investigate cost-effective staffing decisions under various resident census and acuity scenarios. The proposed work will serve as a decision support toolset for SNF administrators to improve their staffing decisions.

## 2 - A Novel Privacy-preserving Positive Transfer Learning Approach for Telemonitoring of Parkinson's Disease

Hyunsoo Yoon, Arizona State University, 699 S. Mill Ave, Tempe, AZ, 85281, United States, Jing Li

Telemonitoring of voice signals of Parkinson's Disease (PD) patients using an At-Home Testing Device is a cost-effective logistically-convenient way to monitor disease progression and optimize treatment. Key challenges in telemonitoring are patient heterogeneity and limited data for each patient. We propose a transfer learning approach, P3TL, which can leverage other patients' information when building a predictive model for a target patient. The unique features of P3TL include intelligent selection of patients to transfer to avoid negative transfer and maintain patient privacy preservation.

## 3 - A Novel Transfer Learning Model for Alzheimer's Disease(ad) Early Detection Using Incomplete Multimodality Image Data

Xiaonan Liu, Arizona State University, Tempe, AZ, United States, Kewei Chen, Teresa Wu, David Weidman, Fleming Lure, Jing Li

Early detection of AD is critically important for treatment of this devastating disease. Use of multimodality images has been shown to hold great promise. The challenge is that images of different modalities are not universally available to all patients due to cost and accessibility constraints. We propose a novel incomplete-modality transfer learning (IMTL) model that learns a diagnostic model for each patient sub-cohort with the same availability of image modalities while coupling the model training processes to allow knowledge transfer. IMTL achieves significantly better accuracy than existing single learning models on datasets collected by the AD Neuroimaging Initiative (ADNI).

#### 4 - A Deep Active Survival Analysis Approach for Precision Treatment Recommendations

Kai Yang, Wayne State University, 4815 Fourth Street, Detroit, MI, 48201, United States, Milad Zafar Nezhad,

Survival analysis has been developed and applied in the number of areas including manufacturing, finance, economics and healthcare. In healthcare domain, usually clinical data are high-dimensional, sparse and complex and sometimes there exists few amount of time-to-event (labeled) instances. Therefore building an accurate survival model from electronic health records is challenging. With this motivation, we address this issue and provide a new survival analysis framework using deep learning and active learning with a novel sampling strategy. In the experimental study, we apply our approach on SEER-Medicare data related to prostate cancer among African-Americans and white patients.

#### 5 - A Tensor Factorization Approach to Predicting Clinical Outcomes

Qingpeng Zhang, City University of Hong Kong, 83 Tat Chee Avenue, 6/F, Academic 1, Kowloon, 12180, Hong Kong,

In this talk, I am going to introduce the tensor factorization based models for the prediction of various clinical outcomes at the individual level. In particular, we focus on the prediction of chronic diseases and re-admissions of the elderly. Experiments with EHR data in Hong Kong will also be presented.

### ■ TA60

West Bldg 102B

#### Feryal Erhun

Sponsored: Health Applications

Sponsored Session

Chair: Feryal Erhun, University of Cambridge, Cambridge, CB2 1AG, United Kingdom

#### 1 - Data-driven Machine Learning Algorithm for High-priority Drug-drug Interactions Discovery

Ning Liu, Penn State University, 233 Leonhard Building, University Park, PA, 16802, United States, Qais Hatim, Soundar Kumara

Drug-drug interactions (DDIs) are the primary causes for adverse events and have become serious concerns for both drug discovery and pharmacovigilance. Unfortunately, the identification of DDIs is challenging and require domain knowledge and enormous efforts from experts. The FDA Adverse Event Reporting System routinely collects adverse event reports from patients and provides a rich data source to discover unknown DDIs. We propose a machine learning method to find patterns from known high-severity DDIs and predict pairs of drugs that may potentially interact and result in adverse events. Our data-driven approach incorporates domain knowledge and provides an option for detecting DDIs.

#### 2 - Outreach and Mobile Clinic Strategies for Vaccine Distribution

Yuwen Yang, PhD Candidate, University of Pittsburgh, 3700 O'Hara Street, Benedum Hall of Engineering, 1043A, Pittsburgh, PA, 15261, United States, Hoda Bidkhori, Jayant Rajgopal

In many low and middle income countries with geographically dispersed populations, last-mile vaccine delivery can be a complex process. Remote locations in these countries often do not have direct access to clinics/hospitals, and residents often face significant difficulty in obtaining routine vaccinations. An approach known as outreach is typically utilized to raise immunization rates in these situations. A set of these remote population centers are chosen as mobile clinics, and clinicians and support personnel are sent from a depot to each team to vaccinate people in the immediate surrounding area. We formulate this process as a mixed integer programming problem and discuss related issues.

#### 3 - The Determinants of Process Innovation in the Pharmaceutical Industry

Ivan Lugovoi, HEC Paris, 1 Square Theodore Judlin, Paris, 75015, France

Utilizing a unique dataset of the process - patent expert evaluations merged with the sales of 50 generic pharmaceutical products over a 10-year period across 4 countries, we observe that process innovation is associated with a significant increase in a firm's market share. To explain the origins of this effect we explore how market determinants: market concentration and growth, product lifecycle, and price elasticity, and technology determinants: vertical integration, technological diversification, and opportunity affect three dimensions (novelty, scope, and locus) of process innovation

#### 4 - Capacity Management in New Drug Development:

##### A Contract Research Organization Perspective

Sjors Jansen, PhD Candidate, Eindhoven University, P.O. Box 513, Paviljoen E13, Eindhoven, 5600MB, Netherlands

In recent years, pharmaceutical companies outsourced the development of new drugs to Contract Research Organizations (CROs). CROs conduct the development of a new drug for a fixed fee. CROs have a large research capacity, which they aim to fill with profitable research projects. Each project consists of multiple phases. Due to the uncertainty in the outcome of project phases, the

required capacity in the future is uncertain. Existing literature considers the problem from the perspective of a pharmaceutical company. CROs have different incentives and make different trade offs. Therefore, we model the capacity problem from a CRO's perspective to help a CRO to select projects from pharma companies.

### ■ TA61

West Bldg 102C

#### Joint Session HAS/Practice Curated: Operations Research in Hospital Operations

Sponsored: Health Applications

Sponsored Session

Chair: Miao Bai, PhD, Mayo Clinic, Rochester, MN, 55904, United States

#### 1 - Dynamic Coordination of Exams in the Radiology Practice

Miao Bai, Mayo Clinic, Rochester, MN, 55904, United States, Mustafa Y. Sir, Kalyan Pasupathy

Radiology exams vary significantly in duration and technology requirements. Coordination between various exams with stochastic duration and requiring different scanner technology is challenging but essential to the timely fulfillment of demand and the efficient utilization of expensive scanner resources. Radiology exam coordination is further complicated by the great number of unscheduled exam requests that need to be completed within a specific time frame. To address this problem, we developed a real-time radiology exam coordination system based on a dynamic programming framework.

#### 2 - Generalizability Among Hospitals that Percentages of Surgical Cases During Weekends or Holidays Change Proportionally with Total Caseload Over Decade

Franklin Dexter, Professor, University of Iowa, 200 Hawkins Dr, 6JCP, Iowa City, IA, 52242, United States, Richard Epstein

Previous studies showed how to calculate weekend and holiday anesthesia staffing to assure no greater than a prespecified percentage of days with =1 surgical case waiting longer than at baseline. We used Iowa Hospital Association data, Jan 2007 - Jun 2017; N = 42 hospitals with =10 cases during weekends or holidays per period. We confirmed that over many (10) years hospitals' proportions of cases performed on weekends and holidays remain stable. The implication is that weekend and holiday staffing can be reevaluated annually, the interval over which changes in total caseloads are evident.

#### 3 - Mathematical Methods for Efficient Allocation and Utilization of Hospital Resources

Tracey Hong, Stanford University, Stanford, CA, United States, Emily Grimm, Michael Fairley, Steven Frick, David Scheinker, David Scheinker

The rising cost of healthcare is increasing pressure on hospitals to improve the value of care, but hospitals often lack access to modern quantitative methods to maximize the efficiency of resource allocation and utilization. Many mathematical models have been developed to better inform hospital decisions, but relatively few have been implemented. We describe examples of several models, designed and implemented, at Lucile Packard Children's Hospital Stanford, including optimal surgeon scheduling with integer programming, patient volume forecasting, bed assignments via simulation, and nurse staffing with a regression model. We emphasize the components that made implementation possible.

#### 4 - Analytics Systems to Improve the Value of Surgical Care

David Scheinker, Stanford - Lucile Packard Children's Hospital, Huang Engineering Center, 475 Via Ortega, Stanford, CA, 94305, United States

Variability in surgical supplies, procedure durations, operating room utilization, patient arrival rates to the PACU, and post-operative inpatient lengths of stay are associated with delays in care, staff frustration, and higher medical costs. Improving these processes with manual reviews and revisions can be prohibitively time consuming. We give an overview of the design and implementation of partially automated systems that use EMR data to reduce the variability, errors, and costs associated with these processes. The methods used include dynamic Bayesian networks, machine learning, causal inference, integer programming, and discrete event simulation.



## ■ TA62

West Bldg 103A

### Mining Unstructured Data

Sponsored: Data Mining

Sponsored Session

Chair: Erhun Kundakcioglu, Ozyegin University, Istanbul, Turkey

Co-Chair: Mustafa Gokce Baydogan, Bogazici University, Istanbul, 34342, Turkey

#### 1 - Nested Gaussian Process for Unstructured Data Mining

Hui Yang, Pennsylvania State University, 310 Leonhard Building, Industrial and Manufacturing Engineering, University Park, PA, 16801, United States

Modern healthcare systems are increasingly investing in advanced sensing and information technology, leading to data-rich environments in hospitals. However, heterogeneous types of sensing and measurement methods often result in data uncertainty and incompleteness. Missing values are not uncommon for clinical variables pertinent to a patient's health conditions. This adversely affects data-driven decision making in the healthcare environment. This paper presents a novel nested Gaussian process (NGP) model that is tailored to represent multi-dimensional covariance structure of time, variable and patient for high-dimensional unstructured data mining in healthcare systems.

#### 2 - Understanding Student Enrollment through Unstructured Test Response Data Analysis

Petros Xanthopoulos, Stetson University, 421 Woodland Blvd, DeLand, FL, 32723, United States, Berry T. Cox

Free text response is very important in education analytics. Survey responses might encapsulate information and insights that could help an institution improve its services and adjust better to the needs of future students. In this presentation we present out analysis for understanding the connection between early post campus visit student surveys and university enrollment. In our study we incorporate natural language processing and machine learning in order to uncover markers that would help us predict factors of importance for predicting student enrollment.

#### 3 - A Sparse Graph-regularized Cox Model for Hot Spot Search on 3-D Radiation Dose Map in Cardiac Toxicity Assessment of Lung Cancer

Xiaonan Liu, Arizona State University, 699 S. Mill Avenue, Tempe, AZ, 85281, United States, Mirek Fatyga, Jing Li

Recent clinical trials on dose escalation in radiation therapy of lung cancer found decrease in overall survival (OS). This unexpected result has driven the research society to study potential damage of radiation to the heart, known as cardiac toxicity. Existing studies focus on finding features in dose-volume histogram (DVH) that are correlated with the toxicity or OS. However, DVH collapses the 3-D dose map into 2-D and thus losing spatial information of dose distribution. We propose a novel sparse graph-regularized cox model to find localized regions (hot spots) in the 3-D dose map of the heart to predict OS. This work enables better treatment planning for lung cancer with awareness of cardiac risk.

#### 4 - Maximizing Area Under Receiver Operator Characteristic Curve for Multi-Instance Learning

Erhun Kundakcioglu, Ozyegin University, Faculty of Engineering, Nisantep mah. Orman sok., Istanbul, 34794, Turkey

The purpose of this study is to solve the multi-instance classification problem by directly maximizing the area under ROC curve. We derive a mixed integer linear programming model that produces the best possible hyperplane-based classifier for multi-instance classification and present cross validation (CV) results for benchmark instances.

## ■ TA63

West Bldg 103B

### Recent Advances in Structured and Non-convex Optimization for Machine Learning

Sponsored: Data Mining

Sponsored Session

Chair: Dzung Phan

#### 1 - Inexact SARAH for Solving Stochastic Optimization Problems

Lam Nguyen, IBM Thomas J. Watson Research Center, Yorktown Heights, NY, United States, Katya Scheinberg, Martin Takac

We consider a general stochastic optimization problem which is often at the core of supervised learning, such as deep learning and linear classification. It is not able to apply SVRG and SARAH for this problem since these algorithms require an exact gradient information. We consider Inexact SARAH, which does not require to compute an exact gradient at each outer iteration; and analyze it in

strongly convex, convex, and nonconvex cases. We also compare it with some existing stochastic algorithms.

#### 2 - Asynchronous Decentralized Accelerated Stochastic Gradient Descent

Yi Zhou, ISyE Georgia Tech, 755 Ferst Drive, NW, Atlanta, GA, 30332, United States, Guanghui Lan

In this work, we introduce an asynchronous decentralized accelerated stochastic gradient descent type of method for solving stochastic convex optimization problems defined over multiagent networks. Considering that communication and synchronization are the major bottlenecks in decentralized optimization, our main goal in this talk is to present algorithmic frameworks which can significantly reduce communication and synchronization costs. We established  $O(\frac{1}{\epsilon})$  (resp.  $O(\frac{1}{\sqrt{\epsilon}})$ ) rate of convergence for our proposed method when the problem is general convex (resp. strongly convex).

#### 3 - L0-regularized Sparsity for Probabilistic Mixture Models

Dzung Phan, IBM Research, 1101 Kitchawan Road, P.O. Box 218, Yorktown Heights, NY, 10598, United States, Tsuyoshi Ide

This talk revisits the task of learning probabilistic mixture models. Our major goal is to sparsely learn the mixture weights to automatically determine the right number of clusters. The key idea is to use a novel Bernoulli prior on the mixture weights in a Bayesian learning framework, and formalize the task of determining the mixture weights as an L0-regularized optimization problem. By leveraging a specific mathematical structure, we derive a quadratic time algorithm for efficiently solving the non-convex L0-based problem. In experiments, we evaluate the performance of our proposed approach over existing sparse methods in terms of accuracy and scalability on synthetic and real data sets.

#### 4 - Scaling Up Optimization Using Non-convexity, Provably

Anastasios Kyriillidis, 1616 Guadalupe Street, Austin, TX, 78701, United States

In this talk, I will focus on the problem of low rank matrix inference in large-scale settings. Such problems appear in fundamental applications such as structured inference, recommendation systems and multi-label classification problems. I will introduce a novel theoretical framework for analyzing the performance of non-convex first-order methods, often used as heuristics in practice. These methods lead to computational gains over classic convex approaches, but their analysis is unknown for most problems. This talk will provide precise theoretical guarantees, answering the long-standing question "why such non-convex techniques behave well in practice?" for a wide class of problems.

## ■ TA64

West Bldg 104A

### Joint Session DM/Practice Curated: Data Science for Novel Applications

Sponsored: Data Mining

Sponsored Session

Chair: Durai Sundaramoorthi, Washington University in Saint Louis, Washington University in Saint Louis, Saint Louis, MO, 63131, United States

Co-Chair: Sundar Victor, Aetna, New York, NY, United States

#### 1 - Study of Mobility in Private Homes

Yan Wang, University of South Florida, Industrial and Management Systems Engineering, 4202 E. Fowler Ave, ENB118, Tampa, FL, 33620, United States, Ali Yalcin, Carla VandeWeerd

Human mobility is shown to be fundamentally regular and potentially predictable based on the study of large-scale geo-location data available through cellular networks and mobile devices. In this work, we study the mobility of residents in private homes, as opposed to outdoor environments. Indoor mobility prediction has far-reaching applications in smart homes and ambient assisted living environments. Using data from ambient sensors, we represent the occupant's movement trajectory as a sequence of symbols and calculate its entropy and an upper bound of its predictability. Our results show that indoor mobility is also predictable and can be quantified.

#### 2 - Deep Neural Networks and Insurance Cross-selling

Xiaoguang Tian, University of North Texas, 1155 Union Circle, Denton, TX, 76203-5017, United States

In this study, we propose applying deep neural networks and ensemble approach to identify the customer who will purchase a new caravan insurance policy and improve the model performance through tuning the parameters. The results show that the approach is effective and outperforms the baseline model on multiple measurements, such as accuracy, sensitivity, and ROC.

### 3 - Forecasting Demand Distribution for New Products using Subjective Rankings

Marat Salikhov, PhD Student, INSEAD, 1 Ayer Rajah Ave, Singapore, 138676, Singapore, Nils Rudi

We present a framework for demand distribution forecasting for new products that combines historical data for similar products with subjective ranking inputs. The framework is based on the decomposition of a demand vector into aggregate, ordered proportion and ranking components, with historical data being used to forecast the first two components and subjective inputs for the last one. The component forecasts are then combined via a simulation-based method. We propose multiple specifications for each of the components. Finally, we evaluate the out-of-sample performance of the method using actual demand data and subjective inputs from a retail company.

### 4 - A Data Glove Based American Sign Language Interpreter

Sara Masoud, University of Arizona, 1127 E. James E. Rogers Way Room 111, Tucson, AZ, United States, Bijoy Dripta Barua Chowdhury, Young-Jun Son

Sign language recognition is a central research problem in computerized gesture detection for enabling hearing impaired people. In this work, a real-time hand gesture recognition framework is proposed to detect the 26 sign language alphabets. VMG 30 data gloves are utilized by which each hand gesture is reported as a 132-feature vector. Feature extraction is performed via a linear discriminant analysis to reduce the size of input vectors to a 25-feature vector and decrease the chance of overfitting. Decision tree models are developed to detect the 26 sign language alphabets based on the 25-feature vector values. The proposed framework has shown a success rate of 98.23% in a real-time environment.

## ■ TA65

West Bldg 104B

### Flash Session – Applied Probability

Sponsored: Applied Probability

Sponsored Session

Chair: Rami Atar, Technion, Technion, Haifa, 32000, Israel

Co-Chair: Harsha Honnappa, Purdue University, West Lafayette, IN, 47906, United States

#### 1 - Session on Open Problems in Applied Probability

Harsha Honnappa, Purdue University, 315 N. Grant Street, West Lafayette, IN, 47906, United States

Short presentations on open problems in Applied Probability (broadly defined), followed by discussion of the problem.

## ■ TA66

West Bldg 105A

### Reinforcement Learning for Supply Chain and Inventory Optimization

Sponsored: Artificial Intelligence

Sponsored Session

Chair: Afshin OroojlooyJadid, Lehigh University, 200 West Packer Ave, Bethlehem, PA, 18015, United States

Co-Chair: Mohammadreza Nazari, Lehigh University, Bethlehem, PA, 18015, United States

#### 1 - A Deep Q-network for the Beer Game: A Reinforcement Learning Algorithm to Solve Inventory Optimization Problems

Afshin OroojlooyJadid, Lehigh University, 15 Duh Drive, Bethlehem, PA, 18015, United States, Mohammad Reza Nazari, Lawrence V. Snyder, Martin Takac

Beer game is a multi-agent serial supply chain in which agents attempt to minimize the total cost of the network given that each agent only observes its own local information. We propose a Deep Q-Network to solve this problem. Our algorithm outperforms approaches from literature and unlike the majority of them does not impose restrictions on the problem parameters, and works well even if other agents do not follow rational policies. Moreover, we propose a transfer learning approach to quickly train new agents with new cost coefficients or action space. The algorithm can be extended to any decentralized multi-agent cooperative game with partial information, which is a common situation in supply chains.

### 2 - A Deep Reinforcement Learning Approach for Dual Sourcing Inventory Management

Joren Gijsbrechts, KU Leuven, Leuven, Belgium, Robert Boute, Dennis Zhang, Jan Van Mieghem

The optimal dual sourcing replenishment policy with non-consecutive lead times does not have a simple structure and is highly state dependent. We model the dual sourcing problem as a Markov Decision Process, and compare three machine learning algorithms based on deep reinforcement learning to solve this analytically intractable problem. Our results show that in the traditional settings our algorithms match (and slightly outperform) the current best-in-class heuristics. Additionally, we develop an experiment including more realistic constraints such as non-linear ordering costs and non-stationary demand showing how machine learning can be applied in a more generalized setting.

### 3 - Returns Optimization

Ajay Deshpande, IBM Research, 1101 Route 134 Kitchawan Rd, Yorktown Heights, NY, 10598, United States, Brian Quanz, Ali Koc, Yada Zhu, Jae-Eun Park

Growth in e-commerce has spurred growth in online returns. IBM Research developed a returns optimization solution which finds an optimal location in a network to maximize net expected recovery on returns. Using learning based optimization we demonstrated significant potential of incremental revenue and logistics cost savings for a large fashion retailer.

## ■ TA67

West Bldg 105B

### Natural Language Processing and User Generated Content

Sponsored: Information Systems

Sponsored Session

Chair: Nicholas Sullivan, University of Utah

#### 1 - Understanding User Engagement in Social Media Through Neural Network-Based Text Mining

Michael Lee, University of Nevada Las Vegas, 1142 West 200 North, Unit A406, Centerville, UT, 84014, United States

Abstract not available.

#### 2 - How do Traditional Rivals Compete on Online Social Media Platforms? An Empirical Investigation

Mikhail Lysyakov, University of Maryland, Robert H. Smith School of Business, College Park, MD, 20783, United States, Kunpeng Zhang, Siva Viswanathan

The evolution of social media platforms has generated new channels for firms to compete with their rivals. There is very little research on how traditional rivals compete on social media and what the effects of such competition are for related outcomes. To address the gap, our paper examines how firms compete on Twitter. We focus on firms that are close competitors in the traditional context and examine whether these traditional rivals also compete closely (i.e. adopt similar strategies) on Twitter. We find evidence of both isomorphism and divergence among traditional rivals in their online social media content strategies. Interestingly, we find that divergence is linked to higher online engagement.

#### 3 - Master, Jedi, or Guru? Normalizing Job Titles in an Ever-Changing Environment

Nicholas Carson Sullivan, University of Utah, 5752 W. Kintail Ct, West Valley, UT, 84128, United States

In this project, we explore different ways to address the issue of job title normalization. This task has been addressed previously as a way to assess different text classification approaches or advanced word-embedding methods. However, we approach the issue in an attempt to create workable data that can be used to create a more effective job recommender system. Such a system would need to be built on a highly standardized and normalized dataset. Job title normalization is a difficult problem not only because there are often different names for very similar jobs (i.e. Software Developer vs. Software Engineer), but also because it is becoming a common practice to intentionally make up creative job titles for the same jobs (i.e. Java Jedi, Software Guru). Unlike previous work addressing similar tasks, we take advantage of the fact that job titles do not exist in isolation. Throughout a career, an individual will hold many different job titles in a sequential order. For any given job title, valuable information can be learned by looking at the job titles held by the individual before and after the given title. We leverage this information to propose new methods to address the task of job title normalization.

#### 4 - Exploring the True Meaning Behind Words: The Lexicon Creation for Investor Sentiment

Keli Xiao, Stony Brook University, College of Business,  
Stony Brook, NY, 11794, United States, Liang Zhang

We develop an effective lexicon based on multi-sources for accurately differing positive and negative sentiments of investors, and help direct financial comments to their actual meanings. Specifically, we apply an efficient prediction-based neural network model to produce domain-specific lexicons for short financial texts, such as bullish and bearish comments in tweets, blogs and news headlines. We evaluate the generated investor sentiment lexicon based on the performance in unsupervised classification and supervised linear classification, as well as in a nonlinear deep learning method for sentiment classification. Our results shows that new lexicons outperforms existing lexicons.

#### ■ TA68

West Bldg 105C

#### Advanced Maintenance Models

Sponsored: Quality, Statistics and Reliability

Sponsored Session

Chair: Yisha Xiang

#### 1 - Maintaining Systems with Heterogeneous Spare Parts

David Tarek Abdul-Malak, University of Pittsburgh,  
1702 Janney Street, Pittsburgh, PA, 15206-1146, United States,  
Jeffrey P. Kharoufeh

We present a periodic maintenance model for systems maintained with spares that originate from a heterogeneous population, i.e., one with multiple system qualities that are visually indistinguishable. At inspection epochs, a failed system can be correctively repaired or replaced, and a non-failed system can be preventively repaired, replaced, or allowed to continue operating. Repairs place the same system back into service, allowing an operator to update their belief about the active system's quality and utilize this information for decision making. A mixed observability Markov decision process model is formulated and structural results, as well as numerical illustrations, are presented.

#### 2 - Maintenance Model for a Stochastically Degrading System with Individually Repairable Components

Nooshin Yousefi, Rutgers University, Piscataway, NJ, United States,  
Jingyu Chen, David W. Coit

An optimal maintenance model is presented for systems with individually repairable components subject to degradation and random shocks. Previous research often focuses on individual components or one component systems, or systems of components that are replaced at the same time. In practice, it is more economical to repair individual components. However, when this happens, each component within the system can have a different age at the beginning of an inspection interval, and once the system gets into steady-state behavior, the component ages become independent. To minimize system cost rate, optimal on-condition thresholds and a system inspection interval are determined.

#### 3 - Condition-based Maintenance Optimization for Multi-component Systems: A Stochastic Programming Approach

Yisha Xiang, Lamar University, 2626 Cherry Engineering Building,  
Beaumont, TX, United States, Zhicheng Zhu

Condition-based maintenance (CBM) is an effective way to reduce system failure and operating costs with real-time information incorporated. However, most studies of CBM focus on single-component systems, which are not applicable to multi-component systems due to the various interactions between components. In this research, we propose a novel multi-stage model by using stochastic programming, which aims at providing optimal maintenance decisions for complex multi-component systems. Chance constraints are incorporated into this model to guarantee the satisfaction of predetermined budget and the requirement of system's reliability and availability.

#### 4 - Do Routine Breast Cancer Screenings Save Lives?

##### A Maintenance-based Model for Evaluating Current Screening

Suzan Alaswad, Zayed University, Khalifa City A, Office FF1-2-  
010, Abu Dhabi, United Arab Emirates, Sinan Salman

There is controversy regarding breast cancer screening - many scientists debate on the benefits of routine screenings on reducing deaths. In this paper, we evaluate the efficacy of current breast cancer screening policies using a condition-based maintenance model. Screening policies similar to inspection policies can be used to reduce cancer mortality rates. In this study, we model survival time from cancer diagnosis to breast cancer mortality using hypertabastic proportional hazards model. The progression of breast cancer is modeled using a partially observable Markov model. The combined model is used to find the reduction of breast cancer mortality under different screening policies.

#### ■ TA69

West Bldg 106A

#### Modeling, Monitoring, and Prediction in Complex Systems

Sponsored: Quality, Statistics and Reliability

Sponsored Session

Chair: Xiaochen Xian, Madison, WI, 53705, United States

Co-Chair: Kaibo Liu, UW-Madison, Madison, WI, 53706, United States

#### 1 - Radiomics 2.0: Integration of Machine Learning and Mechanistic Models for Brain Tumor Mapping Using Multiparametric Magnetic Resonance Imaging

Nathan B. Gaw, Graduate Research Associate, Arizona State  
University, 699 S. Mill Ave, Tempe, AZ, 85258, United States,  
Jing Li

Glioblastoma (GBM) is the most aggressive type of brain cancer. Using multiparametric Magnetic Resonance Imaging (MRI) to quantify intra-tumor cell density distribution for each patient is critical for precision treatment. This falls in the field of "radiomics". Both data-driven machine learning (ML) and cell-biology-based mechanistic models have been developed, but each model has its limitations. We develop a first-of-its-kind hybrid model that integrates semi-supervised ML and a mechanistic model of GBM cell proliferation and invasion (PI), namely the ML-PI model. ML-PI achieves higher accuracy than ML or PI used alone, and produces biologically compliant cell density maps.

#### 2 - A Generic Health Index Approach for Multisensor Degradation Modeling and Sensor Selection

Minhee Kim, University of Wisconsin-Madison, Madison, WI,  
United States, Changyue Song, Kaibo Liu

With recent development in sensor technology, multiple sensors have been widely adopted to monitor the degradation of a single unit simultaneously. This study proposes a novel data fusion method that constructs a one-dimensional health index via automatically selecting and combining multiple sensor signals to better characterize the degradation process. In particular, we develop a new latent linear model that constructs the health index and selects informative sensors in a unified manner. Simulation studies and a case study are presented to illustrate the effectiveness and evaluate the prognostic performance of the proposed method.

#### 3 - Causation-based Monitoring and Diagnosis for Multivariate Categorical Processes with Ordinal Information

Xiaochen Xian, Madison, WI, 53705, United States, Jian Li,  
Kaibo Liu

In this paper, we leverage Bayesian networks to characterize Multivariate Categorical Processes (MCPs) with a causal structure, where the categorical variables can be either nominal, ordinal, or a combination of both. We develop one general control chart and one directional control chart, both of which fully exploit the causal relationships and the ordinal information for better process monitoring and diagnosis. Numerical simulations have demonstrated the superiority and robustness of our method in detecting and diagnosing the conditional probability shifts of nominal factors as well as the conditional latent location shifts of ordinal factors.

#### 4 - Change Point Detection in a Multivariate Process

Rong Pan, Arizona State University, School of Computing  
Informatics & Decision Sys, P.O. Box 878809, Tempe, AZ, 85287-  
8809, United States, Steve Rigdon

In this talk we present a computational Bayesian method for change point detection and compare its performance with other traditional control charts.



## ■ TA70

West Bldg 106B

### Estimation Issues in Frontier Estimation

Emerging Topic: Productivity, Efficiency and Data Envelopment Analysis

Emerging Topic Session

Chair: John Ruggiero, University of Dayton, Dayton, OH, 45469-2251, United States

#### 1 - A New Family of Copulas, with Application to Estimation of a Production Frontier System

Artem Prokhorov, University of Sydney Business School, Sydney, Australia

We consider a system of equations where one equation is a production function and the others are the first order conditions for cost minimization. The production function equation contains a one-sided error that represents technical inefficiency. The cost minimization equations contain errors that represent allocative inefficiency. If technical and allocative inefficiency are not independent, we encounter the issue that common copulas do not capture the type of dependence that the economic model implies. We design a new copula family that does capture the right type of dependence and illustrate how to use it in practice. This is joint work with C. Amsler and P. Schmidt.

#### 2 - Hinging Hyperplanes as a Nonparametric Estimator

Ole Bent Olesen, University of Southern Denmark, Campusvej 55, Odense M, DK-5230, Denmark, John Ruggiero

Nonparametric estimators with shape constraints of production functions/frontiers have recently received attention in the literature. In this paper we focus on the hinging hyperplane approach suggested by Breiman in 1993. An unknown function is approximated by a sum hinge functions, where each hinge function can be expressed as a sum of two hyperplanes. The intersection of the hyperplanes is denoted a hinge. Using simulation we show how well the hinging hyperplane approach performs compared to other nonparametric estimators. We define several types of hinges and discuss the possibility of using hinge finding algorithms to decide which types of hinges to use in a grid search.

#### 3 - The Half-Normal Normal Stochastic Frontier Model: An Improved Understanding

John Ruggiero, University of Dayton, Dayton, OH, United States

In this paper, we analyze an error structure defined by the convolution of a normal distribution and a half normal distribution. The resulting skewed normal distribution has been widely used in production economics, perhaps for mathematical convenience. The normal and half-normal distributions allow modeling of statistical noise and production efficiency, respectively. We will focus on estimation of this error structure given its relationship to other distributions.

#### 4 - Using DEA to Eliminate Unnecessary Greenhouse Gas Emissions and Save The Planet

Thomas R. Sexton, Stony Brook University, Stony Brook, NY, United States, Christine Pitocco

We use DEA to analyze the greenhouse gas emissions (GHG) of 172 countries using total GHG as an input, gross domestic product as an output, and human development index and population as site characteristics. Our preliminary analysis finds that 20 countries lie on the efficient frontier and that all countries can reduce their total greenhouse gases by approximately 37%.

## ■ TA71

West Bldg 106C

### Time-Expanded Integer Programming

Sponsored: Computing

Sponsored Session

Chair: Natashaia Boland, Georgia Institute of Technology, Atlanta, GA

#### 1 - Solving Time-Dependent Path Problems with Dynamic Discretization Discovery

Natashaia Boland, Georgia Institute of Technology, Ferst Drive, Atlanta, GA, 30332, United States, Edward He, George L. Nemhauser, Martin W. P. Savelsbergh

Routing in congested networks prompts the need to find paths and associated departure times so as to minimize path duration, where arc travel time depends on the time at which the arc is traversed. We develop an exact dynamic discretization discovery method for the case of piecewise linear travel time functions. Dynamic discretization enables these problems to be solved to optimality by exploring only a small fraction of the breakpoints. Computational experiments show that this fraction decreases as key instance parameters increase, making the algorithm highly scalable. We also generalize the algorithm to minimize total travel time, and demonstrate that it has similar advantages.

#### 2 - Time-expanded Network for Space Mission Planning

Koki Ho, University of Illinois at Urbana-Champaign, 104 S. Wright Street, Talbot Laboratory, Urbana, IL, 61801, United States

This presentation develops a technique based on time-expanded network for human space mission planning and scheduling. As we explore distant destinations like Mars or asteroids, we need a series of flight missions to accomplish the objectives. Logistics and mission planning considerations are critical for those applications. This research will provide a unique solution to this problem using time-expanded network optimization.

#### 3 - Branch-cut-and-price for the Vehicle Routing Problem with Time Windows and Convex Node Costs

Qie He, University of Minnesota, 111 Church Street SE, Minneapolis, MN, 55455, United States, Stefan Irnich, Yongjia Song

Two critical yet frequently conflicting objectives for transportation service companies are improving customer satisfaction and reducing transportation cost. Given a network of customer requests with preferred service times, it is challenging to find vehicle routes and service schedules simultaneously that respect all operating constraints and minimize the total transportation and customers' inconvenience costs. We introduce the Vehicle Routing Problem with Time Windows and Convex Node Costs, in which we model a customer's inconvenience cost as a convex function of its service start time. We propose a branch-cut-and-price algorithm to solve the problem with general convex cost functions.

#### 4 - The Non-Homogeneous Time CIRP

Felipe Lagos, Georgia Institute of Technology, H. Milton Stewart School, 755 Ferst Drive NW, Atlanta, GA, 30332, United States, Natasha Boland, Martin Savelsbergh

We study a continuous time variant of the Inventory Routing Problem (CIRP). The CIRP is the problem of routing vehicles in space and time to deliver product to customers whose demand is a continuous function of time so that customers are never short of product and so that the total delivery cost is minimized. We propose new integer programming models to find good primal and dual bounds for this problem, using these to develop a Dynamic Discretization Discovery algorithm. We prove finite convergence of the algorithm and present computational results, which illustrate the behaviour of the algorithm under different instance characteristics.

## ■ TA72

West Bldg 211A

### Joint Session INFORMS Prize/Practice: 2018 INFORMS Prize

Emerging Topic: INFORMS Prize

Emerging Topic Session

Chair: Tarun Mohan Lal, Mayo Clinic, 200 1st Street Sw, Rochester, MN, 55905, United States

#### 1 - BNSF -2018 INFORMS Prize Winner

Nathaniel O. Richmond, BNSF Railway, The Colony, TX, 75056, United States

BNSF Railway has more than 41,000 employees working to move freight across its sprawling 32,500-mile rail network. To support its complex operational challenges and drive efficiency, BNSF has embraced a data-driven mentality throughout its business. BNSF was awarded the 2018 INFORMS Prize for pioneering and integrating operations research and analytics programs into its organization. This presentation will highlight several innovative applications of these techniques in areas such as capacity expansion, crew management, and equipment maintenance at BNSF.

## ■ TA73

West Bldg 211B

### JFIG Panel Discussion: Advising PhD Students

Sponsored: Junior Faculty JFIG

Sponsored Session

Chair: Chrysafis Vogiatzis, North Carolina A&T State University, North Carolina A&T State University, Greensboro, NC, 27411, United States

Co-Chair: Ehsan Salari, Wichita State University, Wichita, KS, 67260, United States

#### 1 - JFIG Panel Discussion: Advising PhD Students

Chrysafis Vogiatzis, North Carolina A&T State University,  
1601 East Market Street, McNair 405, Greensboro, NC, 27411,  
United States

In this session, we discuss advising PhD students, encouraging creativity and diversity, and guiding/mentoring with successful members of academia. Panelists will share their experiences with advising students who went on to pursue successful careers in academic institutions, research and development environments, and the industry.

#### Panelists

Anna B. Nagurney, University of Massachusetts Amherst, Isenberg School of Management, Dept of Operations & Information Mgmt, Amherst, MA, 01003, United States

Joseph Geunes, Texas A&M University, College Station, TX, United States

Sergiy Butenko, Texas A&M University, 4037 Emerging Technologies Building, Mail Stop 3131, College Station, TX, 77843-3131, United States

## ■ TA74

West Bldg 212A

### Joint Session MCDM/Practice Curated: Novel Applications of Multiple Criteria Decision Technology

Sponsored: Multiple Criteria Decision Making

Sponsored Session

Chair: Jyrki Wallenius, Aalto University School of Business, Helsinki, Finland

#### 1 - A Stepwise Benchmarking Approach to DEA with Interval Scale Data

Jyrki Wallenius, Aalto University School of Business,  
Runeberginkatu 22-24, Helsinki, Finland, Nasim Nasrabadi, Akram Dehnohalaji, Pekka J. Korhonen

Conventional DEA models assume that all variables are measured on a ratio-scale. However, in many DEA applications we have to deal with interval-scale data. In an earlier paper, we proposed a model for efficiency analysis using interval-scale data. In this talk, we investigate the concept of benchmarking in the framework of interval-scale data. We propose an algorithm, which results in a path of targets for each inefficient unit.

#### 2 - Helping Atrial Fibrillation Patients with Adherence to Anticoagulation Therapy: Design Framework and Intervention Strategies

Wojtek Michalowski, University of Ottawa, Telfer School of Management, 55 Laurier Avenue E, Ottawa, ON, K1N 6N5, Canada, Mor Peleg, Szymon Wilk, Szymon Wilk, Dymna O'Sullivan, Martin Michalowski, Enea Parimbelli, Marc Carrier

Adherence to therapy is one of the main determinants of treatment success and its poor level leads to a substantial worsening of patient's condition. Research described here addresses issue of medication adherence of older adults with atrial fibrillation who are on anticoagulation therapy for primary stroke prevention. We present a design framework of mHealth solution that implements dominance-based rough set theory to identify behavioral triggers that might impact patients' adherence. We induce rules from patient records capturing and analyze these rules for behavioral triggers. We illustrate proposed approach with simple clinical scenario developed using patient vignettes.

#### 3 - Tradeoff Preservation in Inferring Objective Function Weights in Multiobjective Optimization

Taewoo Lee, University of Houston, E209 Engineering Bldg 2, 4722 Calhoun Rd, Houston, TX, 77204-4008, United States

Given an input solution that may not be Pareto optimal, we present a novel inverse optimization methodology for multi-objective optimization that determines a weight vector producing a weakly Pareto optimal solution that preserves the decision maker's trade-off intention encoded in the input solution.

We introduce a notion of trade-off preservation, which we use as a measure of similarity for approximating the input solution, and show its connection with minimizing an optimality gap. We demonstrate the proposed method using clinical data from prostate cancer radiation therapy.

#### 4 - Estimating the Form of a Decision Maker's Preference Function and Converging to Preferred Solutions

Murat Mustafa Koksalan, Middle East Technical University, Indus Engineering Department, Ankara, 06531, Turkey, Gulsah Karakaya

We estimate the form of an underlying preference function that is assumed to represent the preferences of a decision maker in a multi-objective environment. After estimating the form, we use an algorithm that utilizes the properties of the estimated form in order to efficiently converge to a preferred solution of the decision maker. We develop the necessary theory to estimate the form of the preference function. We test our approach on several instances and show that it works well.

## ■ TA75

West Bldg 212B

### Joint Session MAS/Practice Curated: Personnel and Network Applications

Sponsored: Military and Security

Sponsored Session

Chair: Lee Evans, United States Military Academy, West Point, NY, 10996, United States

#### 1 - Utilizing Healthcare Systems Engineering Tools to Reduce Healthcare Associated Infections

Jose M. Jimenez, Assistant Professor, United States Military Academy, West Point, NY, United States

Healthcare acquired infections (HAIs) have decreased over the last decade. Nevertheless, HAIs are still a burden for healthcare systems all over the world. In addition to the increase in morbidity and mortality of patients that are already at risk, HAIs create economic for healthcare facilities. Although many clinical methods are being utilized to combat HAIs, it is also important to apply holistic, non-clinical solutions. Multidisciplinary approaches provide some of the best tools to gather data, analyze, determine solutions, and apply them. This presentation highlights some of the healthcare systems engineering tools that have assisted in the reduction of HAIs.

#### 2 - Operationalizing Open-source Intelligence on the Korean Peninsula

Steven Song, USMA, West Point, NY, United States

In today's information age, the amount of publicly available information has grown significantly faster than the U.S. Army's ability to fully exploit the potential of open-source intelligence (OSINT). While OSINT, or intelligence derived from publicly available information (PAI), has unique advantages, OSINT is still undervalued and underutilized. This presentation highlights the current state of the U.S. Army OSINT enterprise on the Korean peninsula, captures the gaps, and provides recommendations for better operationalizing OSINT. Key findings indicate additional personnel, training, and partnerships with Korean counterparts are necessary to harness the maximum potential of OSINT.

## ■ TA77

West Bldg 213A

### Emergency Response (1)

Sponsored: Public Sector OR

Sponsored Session

Chair: Laura Albert, University of Wisconsin-Madison, Madison, WI, 53706, United States

Co-Chair: Forough Enayaty Ahangar

Co-Chair: Suzan Iloglu, University of Wisconsin-Madison, Madison, WI, 53705, United States

#### 1 - Ambulance Emergency Response Optimization in Developing Countries: Methodology

Justin J. Boutilier, University of Toronto, Toronto, ON, Canada, Timothy Chan

The lack of emergency medical transportation is viewed as the main barrier to the access and availability of emergency medical care in low and middle-income countries (LMICs). In this paper, we present a robust optimization approach to optimize both the location and routing of emergency response vehicles, accounting for uncertainty in travel times and spatial demand characteristic of LMICs. We then combine our robust optimization approach with two machine learning frameworks and real data from Dhaka, Bangladesh. The focus of this talk is to present our methodology and present insights on policy-related questions in LMICs.

## 2 - A Covering Model for Locating Ridesharing Depots for Hurricane Evacuation

Forough Enayaty Ahangar, University of Wisconsin-Madison, 3267 Mechanical Eng. Building, Madison, WI, 53706, United States, Laura Albert

We study a class of network optimization problems that enhance a hurricane evacuation system using ridesharing. Our research proposes ridesharing in which people with no proper vehicle or access to public transportation can travel to a safe location by vehicle owners willing to share rides. We formulate a model that identifies multiple depot locations among available public locations (e.g., public schools) and assigns available vehicles to travelers based on the vehicle capacities. The goal is to maximize the number of covered travelers needing rides. We conclude with a discussion of preliminary results demonstrating the performance of the proposed model.

## 3 - Dynamic Resource and Equipment Allocation for an Arctic Mass Rescue Event

Mustafa Can Camur, Rensselaer Polytechnic Institute, 66 13th St. BSMT, Troy, NY, 12180, United States, Thomas Sharkey, Martha Grabowski, Clare Dorsey

We present a mass rescue model containing dynamic logistics decisions for a large-scale maritime evacuation in the Arctic with the objectives of minimizing the impact of the event on the evacuees and the total evacuation time. We model the concept of deprivation costs by incorporating priority levels capturing the severeness of evacuees' current medical situation and period indicating the amount of time an evacuee has not received key relief resources. These costs increase with priority level and period. We will discuss experimental results with policy questions.

## 4 - Analyzing Competing EMSs in Emerging Economies

Jungeun Shin, University of Illinois Urbana-Champaign, Urbana, IL, United States, Jugal Garg, Lavanya Marla, Peter Christopher McGlaughlin

We consider Emergency Medical System (EMS) in non-cooperative settings where customers call multiple EMSs. The patient chooses the first ambulance to arrive, causing wastage and opportunity costs for others. We study a simplified setting of two EMSs located at either end of a unit line, and analyze the coverage strategies of the players under such customer behavior. We show this non-cooperative game has a unique symmetric pure Nash equilibrium, and analyze the Price of Non-Cooperation.

## ■ TA78

West Bldg 213B

## Sustainable Transportation/Logistics in Public Sector OR II

Sponsored: Public Sector OR

Sponsored Session

Chair: Sung Hoon Chung, Binghamton University, Binghamton, NY, 13902, United States

## 1 - Pseudo Node Insertion and Robust Optimization Approaches for Drone-Truck Combined Delivery

Jinkun Lee, East Carolina University, Greenville, NC, United States, Sung Hoon Chung

We consider a drone-truck combined delivery problem, the advantage of which can be summarized in two folds: 1) enabling faster delivery of items and 2) expanding delivery areas. We use vehicle routing models and algorithms as a basis for our research and add special features such as pseudo node insertion and robust optimization. The purpose of such added features is to resolve drone-truck synchronization issue and eventually to make the drone-truck combined routing more efficient. We formulate a mixed integer programming problem and apply a heuristic method to solve the model as well as the robust counterpart. We present case study examples and discuss efficacy and efficiency of our proposed approach.

## 2 - Waiting Strategy for the Dynamic Pickup and Delivery Problem with Time Windows in Food Delivery Service

Hyunjoon Kim, Pohang University of Science and Technology (POSTECH), 77 Cheongam-Ro, Nam-Gu, Pohang, Kyungbuk, 37673, Korea, Republic of, Byung-In Kim, Byeongmok Kim

We study a dynamic pickup and delivery problem with time windows in quick food delivery business. The problem has multiple objectives: (1) minimize the total delay time of orders, (2) maximize the number of delivered orders, and (3) balance the delivered orders among used vehicles to make income of drivers even. We propose an efficient solution approach for the problem. In addition, we test existing strategies such as drive-first, wait-first, and stochastic-wait and propose a new strategy to handle the dynamics of the problem. Experimental results demonstrate the effectiveness of the approach.

## 3 - Pothole Repair Using a MIP Approach for Scheduling Jobs with Degradation Rate

Fatemeh Aarabi, Amherst, NY, 14228, United States

We study the processing time scheduling of a network of jobs wherein the processing time of each job deteriorates with its start time. To better understanding, we consider one of the applications of this problem in transportation. Seeking to minimize the total process time of jobs, a MIP model is proposed. We present a model which not only accounts to process highly degraded jobs as soon as possible but also considers travel distances between them. Due to the NP-hard nature of the problem, greedy algorithm and chronological decomposition are presented. Different instances of the problem are examined on the transportation network of Buffalo, NY.

## 4 - Civic Engagement & Community Operational Research: A Case Study of Street Sweeping in Jersey City, NJ

EunSu Lee, New Jersey City University, 200 Hudson Street, Harborside 2, #234H, Jersey City, NJ, 07311, United States, Yi-Yu Chen

This presentation will demonstrate a practice of civic engagement and community operational research using the case study of street sweeping in Jersey City, NJ. New Jersey City University (NJCU) recently initiated a pedagogical framework of civic engagement to achieve a mission of urban public university in New Jersey. The presentation will discuss the procedure of developing a civic engagement course and student activities. The audience will be engaged and participated in discussion during the presentation.

## ■ TA79

Hyatt, Curtis A

## Supply Chain Management I

Contributed Session

Chair: Ozgun Caliskan Demirag, Penn State Erie, The Behrend College, Black School of Business, 5101 Jordan Road Rm Redc 259, Erie, PA, 16563, United States

## 1 - Trust or Screening? A Study of Impacts of Information Asymmetry on Supply Chains

Xinghao Yan, Assistant Professor, The University of Toledo, 2801 W. Bancroft Street, Toledo, OH, 43606, United States, Meng Li

This paper studies the impacts of information asymmetry on the supply chain from the perspective of behavioral operations. A supplier receives demand information from a retailer's "cheap talk". The supplier has two options to deal with information asymmetry and information credibility: trust the information to some extent or information screening. We compare the two options and find that no option always dominates the other. Interestingly, there are cases where both supply chain members and the system are all better off if the supplier trusts the information without information screening.

## 2 - Boundedness and Complexity in Ethical Purchasing Decisions

Xingzhi Jia, PhD Student, Texas A&M University, Wehner Building, 4113 TAMU, 210 Olsen Blvd, College Station, TX, 77843, United States, Haipeng (Allan) Chen, Xenophon Koufteros

This study investigates purchasing manager's decision-making when both financial and ethical considerations are invoked. We empirically demonstrate that individuals exhibit bounded and complex behavioral patterns due to the interplay between financial benefits and ethical considerations. The observed outcome of ethical decision-making may therefore be driven by multiple mechanisms.

## 3 - Coordination of Make to Order Supply Chain with Volume Flexibility

Shan Chang, Huazhong University of Science & Technology, Wuhan, China, Bin Hu, Tingting Wang, Long Ding

We investigated the upstream manufacturer's investment decision of flexible production capacity in a two-stage supply chain with one downstream retailer, and designed a coordination mechanism, a combination of subsidy for the salvage value and punishment to the shortage, to make the both firms be better off.

## 4 - The Framework for Optimal Supplier Evaluation Based on DEA

JaeHyeok Jo, Undergraduate, Kyungpook National University, Daegu, Korea, Republic of, Sungsu Kim

This research's purpose is to propose the framework to evaluate focal company's shoring strategies. As globalization progresses, multinational companies are being exposed to risks of host countries for operations. Although overseas suppliers' assessment is appeared to be important, the evaluating process for shoring strategies have not been drawn enough attention. This study proposes a linear programming based DEA framework to assess foreign suppliers. Also, integer programming model is introduced to offer an optimal shoring strategy to assist management on shoring decisions.



### 5 - Retailers' Order Placement Timing under Competition and Demand Uncertainty

Ozgun Caliskan Demirag, Associate Professor of O&SCM, Penn State Erie, The Behrend College, Black School of Business, 5101 Jordan Road Rm Burke 259, Erie, PA, 16563, United States, Weili Xue

We consider a supply chain with two retailers and a common supplier. Retailers sell differentiated but substitutable products over a limited selling period and face demand uncertainty. We investigate the retailers' timing of their order placement with the supplier in relation to demand realization and identify the equilibrium strategies. Surprisingly, we find that asymmetric order placement strategies can arise as an equilibrium decision for symmetric retailers.

### ■ TA80

Hyatt, Curtis B

### Practice- Supply Chain Management VI

Contributed Session

Chair: Mike Sherwin, Mississippi State University, 1767 Independence Way, Valencia, PA, 16059, United States

#### 1 - Should the Manufacturer Offer an Emergency Order Opportunity with Uncertain Customer Demand

Meimei Zheng, Shanghai Jiao Tong University, Dongchuan Road 800,, Minhang District, Shanghai, 200240, China, Xue-Ming Yuan

We consider a manufacturer-retailer supply chain in the preselling and selling seasons, where the manufacturer can offer the retailer an emergency order opportunity with limited commitment quantity, in addition to the regular order from the retailer before the selling season. Through mathematical modeling and analyzing the supply chain, it is found that when the emergency order opportunity is provided, the manufacturer might be worse off although the retailer is always better off. We derive the conditions where both manufacturer and retailer can benefit from the emergency order, and the supply chain profit can be maximized.

#### 2 - Advertising in a Capital-constrained Supply Chain with Retailers' Different Market Shares

Haijun Wang, Shanghai Jiao Tong University, Huashan Road 1954, Xuhui, Shanghai, 200030, China

We consider a supply chain with a manufacturer (leader) and two retailers (followers), where both retailers advertise to stimulate ad-related demand. One retailer is capital-constrained and has access to bank financing. The retailer goes bankrupt if he cannot pay off his loan obligation. Each retailer has its own market share and unmet demand in one retailer's market share turn to the other retailer to purchase the product. We formulate the problem as a game theory model with the manufacturer and retailers' objective to maximize their own expected profits. Numerical examples are provided to illustrate the impact of advertising on retailers' capital allocation, and their expected profits.

#### 3 - Sourcing Under Multiple Attributes: Cost Sharing Mechanisms

Shivam Gupta, University of Nebraska Lincoln, P.O. Box 880491, Lincoln, NE, 68588, United States, Milind Dawande, Ganesh Janakiraman, Shouqiang Wang

We propose a simple cost-sharing mechanism for a principal procuring service to complete a project under information asymmetry on the agent's cost and non-cost estimate. We establish its near-optimality, and provide valuable insights into the nature of cost-sharing for its use in practice.

#### 4 - An Optimized Resource Allocation Approach to Identify and Mitigate Supply Chain Risks using Fault Tree Analysis

Mike Sherwin, Mississippi State University, Mississippi State, MS, United States, Hugh Medal, Cameron MacKenzie

Low volume high value (LVHV) supply chains such as airline manufacturing, power plant construction, and shipbuilding are characterized by long lead times and a limited number of suppliers that have both the technical know-how and manufacturing capabilities to deliver the requisite goods and services. In this research, we develop novel approaches that provide a set of tools for industry practitioners to predict supply chain risks, optimally choose which risks to mitigate, and make better informed decisions with respect to supplier selection and risk mitigation while avoiding costly delays due to disruptions in LVHV supply chains.

### ■ TA81

Hyatt, Phoenix East

### Optimization I

Contributed Session

Chair: Lakmali Weerasena, University of Tennessee-Chattanooga, 615 McCallie Ave, Chattanooga, TN, 37403, United States

#### 1 - Community Resilience Planning Alternatives Generation

Kenneth Harrison, Operations Research Analyst, National Institute of Standards and Technology (NIST), 8701 Susanna Lane, Chevy Chase, MD, 20815-4713, United States

Math programming (MP) models will be presented that underpin a decision support tool in development at the National Institute of Standards and Technology (NIST). Most broadly, the models address the search for mitigation/preparedness actions at the community scale that shorten the recovery time from natural hazard events while addressing cost, social and political feasibility. Among the phenomena captured are the stochastic nature of disasters and the linkages between the mitigation decisions and post-event decisions. Important inputs include "interdependency networks", including a lines-of-defense, cascading failure, and recovery network.

#### 2 - Sustainable Energy Supply Planning Under the Impact of Climate Change

Cansu Agrali, PhD Student, Purdue University, West Lafayette, IN, United States, Seokcheon Lee, Roshanak Nateghi

Renewable sources (RS) are one of the main part of energy management environment. RS are known for their intermittent nature caused by weather and climate. If RS systems are able to adapt to and even take advantage of the vital climate change, it may be possible to greatly rely on renewable energy sources in the near future. In this study, we investigate a long-term climate-driven energy supply planning model. A mixed integer model is developed and data set is created by using forecasting methodologies. Because of long-term model nature, a heuristic algorithm is needed. Case studies will be conducted with both MILP model and a heuristic algorithm.

#### 3 - Offline Smart Appliance Scheduling in Smart Grid System

Nihat Oner, PhD Candidate, TOBB University of Economics and Technology, Ankara, Turkey, Cansu Agrali

Home energy management systems are seen as a need to reduce the electricity cost and make efficient the energy management. Coupled with the possibility to generate power at a residential level and the energy storage systems, the management of all devices has been getting more complex. In this work, a smart appliance scheduling in isolated smart grid problem is studied. In this network, renewable generators and energy storage systems are included. As a solution technique, 3 algorithms are designed and tested with benchmarks. The main contribution of this study is a cutting plane algorithm which yields an optimal solution in a reasonable time period.

#### 4 - Weighted P-Dispersion Problem

Saeed Chavoshi, NC State University, 3100 Kings Court, Apartment H, Raleigh, NC, 27606, United States, Yahya Fathi

Given a collection of  $p$  facilities with a weight  $w_i$  associated with each facility  $i$ , and a collection of  $n$  locations ( $n=p$ ) with a symmetric distance  $d_{ij}$  between each pair of locations  $i$  and  $j$ , we seek to establish a location for each facility so as to maximize the minimum weighted distance between all pairs of established facilities. We formulate an integer programming model for this problem and propose an effective method for solving the problem by exploiting its relationship with the well known node packing problem. We also present the results of a limited computational experiment.

### ■ TA82

Hyatt, Phoenix West

### Health Care I

Contributed Session

Chair: Salar Ghamat, Richard Ivey Business School, London, ON, N6H 0C4, Canada

#### 1 - The End User Trust Acceptance Model of Genetic Testing Services

Xinyu Wei, University of North Texas, Denton, TX, United States, Heng Xie, Xianghui (Richard) Peng, Victor R. Prybutok

This study investigates end user's perspectives on genetic health risk (GHR) testing services. GHR testing services have expanded dramatically and there is a need to study the trust challenges to end user acceptance of genetic testing services. We develop and test an integrated end user trust model that examines the relationships between trusting bases, trusting beliefs, and trusting intention.

## 2 - Secure Decentralized Decisions in Consolidated Hospital Systems: Intelligent Agents and Blockchain

Adrien Badr, Student, University of Oklahoma, Norman, OK, United States, Shima Mohebbi

Shared decision making and its security have become very important in consolidated healthcare systems. We propose a universal decentralized Decision-Making architecture utilizing trained artificial intelligence for illness detection and Blockchain technology to address the compelling need of coordination among healthcare providers-patients and secure transmission of medical transcripts. Agent-based simulation and optimization will be used to simulate patients' referral process in consolidated hospital systems. We demonstrate the feasibility of the proposed approach via extensive simulation analyses.

## 3 - The Impact of Implementing Full Capacity Protocol on the Operational Performance in an Emergency Department

Lu Wang, PhD Candidate, University of Kansas, Lawrence, KS, 66046, United States, Mazhar Arian, Suman Mallik

Full capacity protocol (FCP) is a set of guidelines that coordinates the patients flow when the emergency department (ED) is overcrowded. Utilizing data from a large urban teaching hospital, we show that the operational performance of the study ED is improved when the FCP is triggered. We propose recommendations to further improve the operational outcomes under FCP. We study how the detailed crowding levels impact patients' length of stay as well as sub-intervals (i.e. waiting time, in-service time and after-service time).

## 4 - Associations Between Hospital Readmission and Length of Stay with Post Acute Referral Following Coronary Artery Bypass Graft or Valve Replacement

Ineen Sultana, Graduate Research Assistant, Texas A&M University, Industrial and System Engineering, College Station, TX, 77843, United States

Hospital readmission and length of stay (LOS) are two key indicators of health care quality. Risk factors associated with hospital readmission and LOS were analyzed for Coronary Artery Bypass Graft and Valve Replacement patients. Results indicated non-uniform care across the U.S. census division and an inversely proportional relation between readmission and LOS. Hospital size, teaching facility, and comorbidity influence LOS, while demographic conditions and support infrastructure influence readmission. Although variation in PAC usage across different region indicates that higher LOS patients were subjected to PAC referral, no direct association of PAC type and readmission was observed.

## 5 - Global Budget Revenue Policy Impact on Emergency Department Efficiency in Maryland

Ai Ren, PhD Student, University of Maryland-College Park, Robert H. Smith School of Business, 3330 Van Munching Hall, College Park, MD, 20740, United States, Bruce L. Golden, Edward Andrew Wasil, Margret V. Bjarnadottir

We conduct an empirical analysis of the impact of Global Budget Revenue (GBR) implementation on Maryland Emergency Department (ED) efficiency measure ED1 from January 2014 to April 2016. We use public data from the Centers for Medicare & Medicaid Services and the Kaiser Family Foundation database. Our study uses Difference in Difference model with mixed effect. We find GBR has statistically significant negative impact on Maryland ED1 efficiency performance but not practically significant.

## 6 - Care-coordination: Gain-sharing Agreements in Bundled Payment Models

Salar Ghamat, Lazaridis School of Business and Economics, 75 University Ave W, Waterloo, ON, N2L 3C5, Canada, Hubert Pun, Greg Zanic

We study gain-sharing agreements, under a bundled payment model, between a hospital and a provider that may cooperate to achieve a desired cost and quality of care collectively. We characterize scenarios that lead to care-coordination between the two parties. We also provide evidence that a target price bundled payment model can be more effective in healthcare settings where the care providers have asymmetric capabilities. We further provide guidance, for the payer, regarding the impact of these models on the health outcome of patients and the total spending.

## ■ TA83

Hyatt, Remington

## Practice- Health Care I

Contributed Session

Chair: David C. Novak, University of Vermont, 310 Kalkin Hall, 55 Colchester Avenue, Burlington, VT, 05405-0157, United States

## 1 - Determining Effective and Practical Colonoscopy Screening and Surveillance Policies

Fatih Safa Erenay, University of Waterloo, Waterloo, ON, Canada, Gizem Sultan Nemutlu, Oguzhan Alagoz

Efficient colonoscopy screening and surveillance policies are desired to cost-effectively reduce colorectal cancer incidence and mortality. We developed a partially observable Markov decision process model to dynamically schedule colonoscopy operations based on accumulated risk of having advanced lesions and other risk-factors. However, clinicians may find such optimal policies too complex to adopt. Using a stochastic model, we derive simple yet effective dynamic colonoscopy policies which perform closely to the optimal policies and are easy-to-implement in clinical practice.

## 2 - A Bayesian Approach to Measuring Healthcare Intervention Impacts

Douglas A. Popken, SVP Analytics, NextHealth Technologies, Inc, 999 18th Street, Suite 2600, Denver, CO, 80202, United States

Measuring the impact of healthcare interventions is challenging due to the random, infrequent, and highly variable nature of follow-on cost and utilization data. While a randomized controlled trial approach reduces measurement bias, standard statistical techniques based on t-tests may not adequately separate signal and noise. Bayesian methods have the advantage of utilizing prior knowledge as well as providing richer output metrics to inform decision makers, both automated and human-in-the loop. We describe our implementation and provide comparative statistics from real-world experience.

## 3 - Economic Assessment of Policies to Prevent Childhood Lead Poisoning

George Miller, Institute Fellow, Altarum, 3520 Green Court, Suite 300, Ann Arbor, MI, 48105, United States, Corwin Rhyhan

Lowering current levels of lead exposure for young children has the potential to improve health, increase earnings, save government expenditures, and reduce disparities. We describe an analysis that estimated the annual economic burden of childhood lead exposure in the U.S. at \$84 billion dollars, including costs of reduced lifetime productivity, increased health care and social assistance spending, and premature mortality. The analysis also identified the potential for residential lead prevention and remediation policies to cut lead exposure levels for young children, resulting in significant long-term economic benefits and in many cases positive net societal returns.

## 4 - A Group Decision Making Approach for Risk Assessment in Distribution of Pharmaceutical Products

Shahrezad Faghil Roohi, Postdoctoral fellow, Eindhoven University of Technology, Eindhoven, Netherlands, Alp Akcay, Yingqian Zhang, Eelco De Jong

This paper presents a group decision making approach for risk assessment in distribution of pharmaceutical products. By using a new intuitionistic fuzzy hybrid TOPSIS approach, we prioritize the risks involved in pharmaceutical distribution. The aim is to overcome the current weaknesses of failure modes and effect analysis (FMEA) method by considering unequal weights of risk factors given by experts for different failure modes. A case study on air cargo distribution of pharmaceutical products is presented to demonstrate the potential applications of the proposed approach, and the merits are highlighted by comparing with the traditional FMEA.

## 5 - Managing Blood Inventory with Random Transfers

David C. Novak, Associate Professor, Grossman School of Business, University of Vermont, 310 Kalkin Hall, 55 Colchester Avenue, Burlington, VT, 05405-0157, United States, Marilyn Lucas, Karti Purnanam

We introduce a method to solve the fixed lifetime perishable inventory problem with a lifetime of  $m > 2$  periods, where there are two independent sources of supply. One source is blood deterministically ordered by the blood bank. The other source is blood that is randomly transferred to the blood bank from smaller, lower-usage hospitals in the health care network. We formulate a DP to solve the multi-period cost minimization problem and test our solution approach theoretically and empirically. We then present a novel heuristic approach for determining a near-optimal ordering policy for any perishable product where redistribution represents a second source of supply.

## ■ TA84

Hyatt, Russell

**Innovation/ Entrepreneurship**

Contributed Session

Chair: Yi He, Tongji University, Shanghai, China

**1 - The Evolving Use of Patents as a Key Marketing Strategy by High-tech Companies**Fang Wan, University of Rochester, Rochester, NY, 14627,  
United States, Avi Seidmann

Advanced technological capabilities constitute a major recourse for firms trying to achieve and maintain competitive advantages. Patented innovations and efforts therefore may determine the firm's strategic direction. We analyze the impact of novel intellectual properties, especially the role of patents, on business strategies, and value creation. Our large-scale empirical research provides managerial suggestions on allocating firms' resources between technological innovations and traditional marketing.

**2 - Methods for Optimizing Technological Maturity in NASA's Small Business Innovation Research Program**Jeremy Eckhause, RAND Corporation, 1200 S. Hayes St.,  
Arlington, VA, 22202, United States, Andrea Belz, Richard Terrile,  
Aleksander Giga, Fernando Zapatero

Projects funded in NASA's two-stage Small Business Innovation Research (SBIR) program vary in their initial, intermediate and final Technology Readiness Level (TRL). From past performance data, we obtain realistic transition probability distributions, enabling us to optimize strategies and budget allocations under various objective functions, such as maximizing the number of projects attaining a desired TRL threshold or those with any TRL progression. We compare models to historic strategies, highlighting the importance of a real options portfolio approach to maximize program outcomes.

**3 - Growing and Developing Capabilities Along the Value Chain to Sustain Innovations in Emerging Markets**Anshuman Tripathy, Indian Institute of Management-Bangalore,  
Bannerghatta Main Road, Bilekahalli, Bangalore, 560076, India,  
Shikha Safaya

Developed markets are characterized by well defined value chains which consist of modular activities (with well defined interfaces) leading to the delivery of the value proposition to the customers. Thus innovations tend to be, in general, incremental and limited to an activity, adopting the existing interfaces to the value chain. Our study of product, process and social innovations in an emerging market shows that such value chains are nebulous and to ensure sustainability of their innovations, the firms need to integrate through the value chain for economic sustainability, often requiring them to invest in assets and capabilities that, though complementary, are unrelated to their innovation.

**4 - The Influence of a Firm's Supply Network on Its Innovation Capability**Shubhbrata Palit, Student, Georgia Institute of Technology, 800  
West Peachtree NW, Atlanta, GA, 30308, United States, Soumen  
Ghosh

In this research, we explore the role of a firm's supply network in driving its innovation capability. Using secondary data, we examine how the diversity and the intensity of the innovation expertise of suppliers as well as the technology overlap of a firm with its supply base impact a firm's innovation capability.

**5 - Exploring the Origins of Successful Ideas on a Open Innovation Setting**Nilam Kaushik, University College London, London,  
United Kingdom

We explore the factors affecting the successful evaluation of ideas on an open innovation platform, in particular, the role of an idea's genealogical sources. We leverage text mining and information retrieval techniques.

**6 - A Study on the Relationship Between Self-Sacrifice in Leadership and Employee Creativity and Its Impact in the Cross-level Regulation of Team Trust**Yi He, Tongji University, Room 2001, No 58 Songyuan Road,  
Shanghai, 200360, China

This research integrates the theory of social learning and existing research findings in order to find out how self-sacrificing leadership can influence the creativity of employees in an organization. The hypothesis was tested positively, (1) self-sacrificing leadership has significant positive predictive effects on the participation in creative processes and the general creativity of employees; (2) participation in creative processes plays an intermediary role in the relationship between self-sacrificing leadership and employee creativity; (3) cross-level team trust adjusts according to the inclusion in processes of participation and affects employee creativity.

**Tuesday, 9:30AM - 10:20AM**

## ■ Plenary

West Bldg 301AB

**Plenary: Adopting a Risk-Based Approach to Passenger Screening**

Plenary Session

Chair: Ali E. Abbas, University of Southern California, 3650 McClintock  
Ave, OHE 310R, Los Angeles, CA, 90089, United States**1 - Adopting a Risk-Based Approach to Passenger Screening**  
Kenneth Fletcher, Kestrel Hawk Consulting, Inc., Gathersburg,  
MD, United States

In 2011, the Transportation Security Administration began piloting a risk-based approach to aviation passenger screening. This effort represented a fundamental change in the government's thinking about aviation security. Today, more than 350 million travelers receive expedited screening, and the approach is widely accepted. Adaptations of the U.S. program are functioning in Canada, Germany, Israel, Netherlands and the U.K. However, during the development of this initiative TSA leaders faced several policy decisions relating to accepting risk, treating passengers differently, and how to segment passengers into risk categories. This talk provides an insiders' perspective on TSA's efforts to implement risk-based security from one of the initiatives leading architects.

**Tuesday, 10:30AM - 12:00PM**

## ■ TB01

North Bldg 121A

**Data-Driven and Robust Optimization II**

Sponsored: Optimization/Optimization Under Uncertainty

Sponsored Session

Chair: Phebe Vayanos, University of Southern California, Los Angeles,  
CA, 90089, United States**1 - Efficient Algorithms for Robust Markov Decision Processes**Clint Chin Pang Ho, Imperial College Business School, London,  
United Kingdom, Marek Petrik, Wolfram Wiesemann

Robust Markov decision processes (MDPs) seek for optimal policies in view of the worst transition kernel from within an ambiguity set that specifies the knowledge about the unknown true Markov process. Although robust MDPs have emerged as powerful modeling tools, robust MDPs have typically been considered to be intractable, except for special cases where the ambiguity sets are rectangular in both the states and the actions. In this talk, we develop tractable solution techniques for robust MDPs whose ambiguity sets are only required to be rectangular in the states.

**2 - Robust Reformulations of Ambiguous Chance Constraints with Discrete Probability Distributions**

Ihsan Yanikoglu

This paper proposes robust reformulations of ambiguous chance constraints when the underlying family of distributions is discrete and supported in a box or an ellipsoidal uncertainty set. Using the robust optimization paradigm, the deterministic counterparts of the (ambiguous) chance constraints are reformulated as mixed-integer programming problems which can be tackled by commercial solvers for moderately sized instances. The associated approach can be easily extended to joint chance constraints, nonlinear inequalities, and dependent data without introducing additional mathematical optimization complexity to that of the original robust reformulation.

**3 - An Iterative Algorithm for Robust Optimization with Decision-dependent Uncertainty Sets**Chrysanthos Gounaris, Carnegie Mellon University, Doherty Hall  
3107, Dept of Chemical Engineering, Pittsburgh, PA, 15213,  
United States, Nikolaos L. Lappas, Anirudh Subramanyam

Uncertain parameters whose realization can be affected by the decision maker, also known as endogenous uncertain parameters, could be modeled within the framework of robust optimization using decision-dependent uncertainty sets. However, existing solution methods that rely on classical duality-based reformulations pose known limitations. We propose a primal branch-and-bound algorithm that generalizes the well-known cutting plane method of Mutapcic and Boyd to the case of decision-dependent uncertainty sets. A comprehensive computational study showcases the advantages of the proposed algorithm over that of existing methods across a variety of applications.



#### 4 - Two-Stage Robust Optimization with Decision-Dependent Information Discovery

Phebe Vayanos, University of Southern California, OHE 310L, University Park Campus, USC, Viterbi School of Engineering, Los Angeles, CA, 90089, United States, Angelos Georgioui, Jiachuan Chen

We consider two-stage robust optimization problems in which part of the first stage variables decide on the uncertain parameters that will be observable in the second stage (as in sensor positioning, patrolling). The state of the art formulates the problem as a two-stage robust problem with decision-dependent non-anticipativity constraints and uses binary decision rules over a preselected partition of the uncertainty set resulting in very conservative solutions. We propose a novel min-max-min-max formulation and a solution method based on the K-adaptability idea. We reformulate the problem as an MLP solvable with off-the-shelf solvers and demonstrate its effectiveness on stylized problems.

#### ■ TB02

North Bldg 121B

#### Sparsity in Regression

Sponsored: Optimization/Optimization Under Uncertainty

Sponsored Session

Chair: Dimitris Bertsimas, Massachusetts Institute of Technology, Cambridge, MA, 02139, United States

##### 1 - A Scalable Algorithm for Sparse and Robust Portfolios

Ryan Cory-Wright, PhD Student, Massachusetts Institute of Technology, Cambridge, MA, United States, Dimitris Bertsimas

We present a cutting-plane method which solves the sparse Markowitz portfolio problem to provable optimality at scale, by exploiting a dual representation of the continuous problem to obtain a closed form representation of the problem's subgradients. We refine the cutting-plane method by deriving an efficient local-search heuristic which exploits these subgradients, embedding the heuristic within the cutting-plane method, and exploiting a correspondence between the convexified dual problem and a rotated QCQP to obtain a strong a priori lower bound. We illustrate the method's effectiveness by obtaining optimal sparse frontiers for major indices including the S&P 500 and the Wilshire 5000.

##### 2 - Sparse Regression Over Clusters: Sparclur

Lea Kapelevich, Massachusetts Institute of Technology, 77 Massachusetts Avenue, Bldg. E40-103, Cambridge, MA, United States, Dimitris Bertsimas, Jack W. Dunn, Rebecca Zhang

We aim to develop machine learning models that combine state of the art accuracy and interpretability. Sparse regression models and decision trees are machine learning methods that aspire to achieve both these properties. In this work, we generalize ideas from new developments in sparse regression and optimal regression trees. We present an integer programming approach for regression tasks arising in tree-based machine learning models, and apply it to prediction problems in healthcare.

##### 3 - Sparse Regression Scalable Algorithms and Empirical Performance

Jean Pauphilet, MIT, Cambridge, MA, 02139, United States, Dimitris Bertsimas, Bart Paul Gerard Van Parys

We address the problem of sparse linear and logistic regression from a discrete optimization perspective. We formulate the problem as a convex integer optimization problem and solve it efficiently using a cutting-plane algorithm. We also propose a fast sub-gradient algorithm to solve its Boolean relaxation and compare our approach with L1 regularization and two methods with non-convex penalties. We demonstrate empirically the performance of our methods in terms of accuracy, false detection rate and computational time, for different regimes of noise and correlation.

##### 4 - Optimistic Robust Optimization with Application to Sparse Regression and Classification

Matthew Norton, Naval Postgraduate School, 1 University Circle, Monterey, CA, 93943, United States

Robust Optimization has traditionally taken a pessimistic, or worst-case viewpoint of uncertainty. We explore an optimistic, or best-case view of uncertainty and show that it can be a fruitful approach to address a wide variety of problems. In the context of robust linear programming, we provide an intuitive method for reducing conservatism. We also find that many problems in machine learning and robust statistics can be interpreted as optimistic robust optimization problems. This includes popular sparsity inducing non-convex regularization schemes and outlier protection methods.

#### ■ TB03

North Bldg 121C

#### Managing IT-based Technology and Services

Sponsored: Technology, Innovation Management & Entrepreneurship

Sponsored Session

Chair: Juliana Hsuan, Copenhagen Business School, Copenhagen Business School, Frederiksberg, DK-2000, Denmark

##### 1 - Soft Data Analytics with Fuzzy Cognitive Maps:

##### Modeling Health Technology Adoption by Elderly Women

Charles M. Weber, Portland State University, Engineering and Technology Management, P.O. Box 751, Portland, OR, 97207, United States,, Noshad Rahimi

Abstract Modeling how patients adopt personal health technology is a challenging problem: Decision-making processes are largely unknown, occur in complex, multi-stakeholder settings, and may play out differently for different products and users. This paper develops a soft analytics approach, based on Fuzzy Cognitive Maps, which is empirically grounded in a case study of how a group of elderly women adopts wearable devices. The approach leads to an adoption model that simulates different product configurations and scenarios that will most likely lead to successful adoption. The model can be used by product developers and rollout managers to support technology planning decisions.

##### 2 - Knowledge Modularity in Social Networks

Nitin Mayande, Tellagence, 6249 NE Carillion Drive, Unit 201, Hillsboro, OR, 97124-8097, United States, Charles Weber

Network Modularity has been used in many previous studies for community detection. The focus of these studies has mostly been on how people connect with each other to form communities. This exploratory study, instead of people, focuses on contextualized communication (knowledge) and explores to see if Network Modularity measure can be used to quantify Knowledge Modularity thereby identifying knowledge structures within a social network.

##### 3 - Uno or Duo? On Creation and Discovery Entrepreneurship Opportunities and Their Interactions

John N. Angelis, Elizabethtown College, Elizabethtown, PA, United States, Moren Levesque, Richard Arend

While the interaction process between opportunity and the entrepreneur who exploits it has been well researched, research on outcomes has been limited. We provide a formalized explanation of how the two main types of entrepreneurial opportunity (i.e., discovery and creation) interrelate across six specific cases. We provide analysis of a modified model of an established partial-equilibrium production chain. Via theory and simulation, we explain how exploitation of creation opportunities can lead to discovery opportunities; how creation (discovery) opportunities are less (more) likely to be profitable when paired with other opportunity type; and spillover and transfer payment scenarios.

##### 4 - Pricing and Service Bundling at a Smartphone Provider

Eric Bentzen, Copenhagen Business School, Frederiksberg, Denmark, Juliana Hsuan

Many of the attributes with respect to pricing services are implied by economic theory, could be modeled, and investigated using relevant data from a company. In this paper, we will study relationship that a large smartphone service provider should be aware of and use in the pricing of bundling services. From a smartphone company we have access to customers and their use of cell phone services, Internet access and other services provided by the company. The dataset has been collected during a period and includes the amount that a large number of customers are willing to pay for each service.

## ■ TB04

North Bldg 122A

### Extended Formulations in Integer Programming and Combinatorial Optimization

Sponsored: Optimization/Integer and Discrete Optimization

Sponsored Session

Chair: Gonzalo Muñoz, Polytechnique Montr al, Montr al, QC, H3T 1N8, Canada

#### 1 - Extended Formulations for Unstructured Integer Programs

Akshay Gupte, Clemson University, Dept. of Mathematical Sciences, O-321 Martin Hall, Clemson, SC, 29634-0975, United States, Amin Khademi, Andrew J. Schaefer

We present a systematic procedure for constructing extended formulations for convex hulls of pure integer programs. Our technique relies on only the data for the LP relaxation, and does not depend on any particular structure of the IP feasible set. A key step in our construction is the use of subadditive duality for integer programming. If the original LP is represented by a totally dual integral system with integral right hand side, then our extension is exactly the LP polyhedron, as desired. Finally, we apply our result to packing and covering problems.

#### 2 - LP & SDP Hierarchies: How to Schedule?

Víctor Verdugo, Universidad de Chile & Ecole normale supérieure, Santiago, Chile

Convex hierarchies are systematic approaches to strengthen a relaxation. In this talk we will focus on how to construct extended formulations using LP and SDP hierarchies for the problem of scheduling identical machines starting from the configuration linear program, and how they fail to obtain gaps arbitrarily close to one even when they are exponentially sized. We then provide some ideas of how we can overcome this negative result in the context of identical machines and how to construct a new family of polynomial sized relaxations with gap arbitrarily close to one.

#### 3 - Formulations for Spanning Tree (and Related Problems) in Planar Graphs

Hamidreza Validi, Oklahoma State University, Stillwater, OK, 74075, United States, Austin Buchanan

In a 2002 Networks paper, Williams proposed an IP formulation for spanning trees of a planar graph. The formulation is remarkably small (using only  $O(n)$  variables) and remarkably strong (defining an integral polytope). In this talk, we show that Williams' formulation is incorrect as stated, providing a binary feasible solution that does not represent a spanning tree. We characterize when this can happen and show how to fix the formulation. We also propose generalizations of the fixed formulation for related problems.

#### 4 - Treewidth-based Extension Complexity Lower Bounds

Gonzalo Muñoz, Polytechnique Montr al, Montr al, QC, Canada, Yuri Faenza, Sebastian Pokutta

In this work, we study the extension complexity of 0/1 sets parametrized by treewidth: a graph-theoretical parameter that measures structured sparsity. If a 0/1 set can be formulated as the set of binary vectors that satisfy a certain system of constraints, and those constraints present a sparsity pattern whose treewidth is  $k$ , then it is known that the extension complexity of the convex hull of the set is  $O(n^2 k)$ . The goal of this work is to prove the existence of 0/1 sets that (nearly) meet this bound, for any arbitrary treewidth level  $k$ . To the best of our knowledge, this is the first work to provide parametric lower bounds on extension complexity based on the treewidth.

## ■ TB05

North Bldg 122B

### Recent Developments and Methods in Nonconvex Optimization

Sponsored: Optimization/Linear and Conic Optimization

Sponsored Session

Chair: Brendan Ames, University of Alabama, Tuscaloosa, AL, United States

#### 1 - Non-convex Factorization Methods for the K-disjoint-clique Problem

Alexander Barnes, University of Alabama

Large-scale semidefinite programming has many applications, including optimal control, computer vision, and machine learning. However, current algorithms for solving semidefinite programs (SDPs) can be time consuming and memory intensive. We look at new heuristics for the solutions of SDPs based on non-convex factorization, the augmented Lagrangian method, and alternating minimization. In particular, we will focus on solutions of semidefinite relaxations for the  $k$ -clique and  $k$ -cluster programs. We will present numerical results illustrating the efficacy of our approach for clustering of real and simulated data.

#### 2 - Landscape of Neural Networks for Binary Classification

Ruoyu Sun, University of Illinois, Urbana-Champaign

We study the landscape of neural networks for binary classification and provide conditions under which the training error is zero at all local minima. Our results provide a few necessary and sufficient conditions; for example, for ReLU and sigmoid activation functions bad local minima exist, while for strictly increasing and convex functions bad local minima disappear. Other conditions include: the neural network should either be single-layered or is multi-layered with a shortcut-like connection, and the surrogate loss function should be a smooth version of hinge loss.

#### 3 - Foundations of Nonconvex and Nonsmooth Robust Subspace Recovery

Tyler Maunu, University of Minnesota

We present a mathematical analysis of a nonconvex energy landscape for Robust Subspace Recovery. We develop generic conditions that ensures recovery of an underlying subspace in corrupted datasets. We further show that if the generic condition is satisfied, a geodesic gradient descent method over the Grassmannian manifold can exactly recover the underlying subspace. We also examine the recovery limits in the case of arbitrary outliers.

#### 4 - Leave-one-out Analysis for Convex and Nonconvex Matrix Completion

Yudong Chen, Cornell University, 223 Frank H.T. Rhodes Hall, School of ORIE, Ithaca, NY, 14853, United States, Lijun Ding

We introduce a powerful technique, Leave-One-Out, to the analysis of matrix completion problems. This technique allows us to obtain entry-wise bounds for iterative stochastic procedures. We demonstrate its power in analyzing two quintessential algorithms for matrix completion: the non-convex approach Singular Value Projection (SVP), and the convex relaxation approach Nuclear Norm Minimization (NNM). For SVP, we prove for the first time that the unmodified form of this algorithm, without sample splitting, converges linearly in infinity norm. For NNM, we study its dual solution and establish the first sample complexity bound that depends optimally on the matrix dimension and condition number.

## ■ TB06

North Bldg 122C

### Joint Session OPT/Practice Curated: Convex Optimization and Applications to Machine Learning

Sponsored: Optimization/Global Optimization

Sponsored Session

Chair: Georgina Hall, Princeton University, Princeton, NJ, 08544, United States

#### 1 - Time-varying Semidefinite Programs

Amir Ali Ahmadi, Princeton University, Dept. of Operations Research&Financial Eng., Sherrerd Hall (room 329), Charlton Street, Princeton, NJ, 08544, United States, Bachir El Khadir

Time-varying semidefinite programs (TV-SDPs) are semidefinite programs whose feasible set and objective function vary continuously over a bounded time interval and whose solution is a bounded measurable function of time. We show that the best polynomial solution of a given degree to a TV-SDP can be found by solving an SDP of tractable size. We also prove that under mild assumptions, polynomial solutions are as good as any bounded measurable solution. Joint work with Bachir El Khadir.

#### 2 - Nonnegative Polynomials and Applications to Learning

Georgina Hall, INSEAD Business School, Boulevard de Constance, Sherrerd Hall, Fontainebleau, 77300, France

In this talk, we show how techniques from sum of squares optimization can be applied to two problems at the interface of machine learning and polynomial optimization. In part (i), we study the problem of learning a monotone polynomial from data. This is motivated by regression problems where the underlying function to be learned is monotone (consider, e.g., the price of a car as a function of its fuel efficiency). In part (ii), we study the problem of optimally decomposing a multivariate polynomials as the difference of two convex polynomials. This is motivated by certain majorization-minimization algorithms used in nonconvex optimization that require such a decomposition.

#### 3 - Design of First-order Optimization Algorithms via Sum-of-squares Programming

Mahyar Fazlyab, University of Pennsylvania, Philadelphia, PA, United States, Manfred Morari, Victor M. Preciado

We use tools from sum-of-squares programming to design iterative first-order optimization algorithms for smooth and strongly convex problems. Our starting point is to develop a polynomial matrix inequality as a sufficient condition for exponential convergence of the algorithm. We then formulate a polynomial optimization, in which the objective is to optimize the exponential decay rate over the tunable parameters of the algorithm (e.g. stepsize, momentum coefficient, etc.). Finally, we use sum-of-squares programming as a tractable relaxation of the proposed polynomial optimization problem. We illustrate the utility of the proposed framework by designing an accelerated method.

#### 4 - Near-Optimal Joint Matching via Convex Relaxation

Yuxin Chen, Princeton University, NJ, United States

Joint matching over a collection of objects aims at aggregating information from a large collection of similar instances (e.g. images, graphs, shapes) to improve maps between pairs of them. Given multiple matches computed between a few object pairs in isolation, the goal is to recover an entire collection of maps that are (1) globally consistent, and (2) close to the provided maps – and under certain conditions provably the ground-truth maps. In this work, we develop a convex relaxation algorithm to jointly match multiple objects that exhibit only partial similarities, given a few pairwise matches that are densely corrupted. The algorithm provably exhibits near-optimal error-correction ability.

### ■ TB07

North Bldg 123

#### Networked Infrastructure Resiliency and Recovery

Sponsored: Optimization/Network Optimization

Sponsored Session

Chair: Sachin Mhatre, North Carolina A&T State University, North Carolina A&T State University, Greensboro, NC, 27408, United States

##### 1 - System Resilience Modeling Under Multi-hazard

Yao Cheng, Beihang University, 37 Xueyuan Road, Haidian District, Beijing, 100191, China

There has been significant development of complex engineered systems in the last two decades. The increasing natural and manmade hazards have caused significant performance disruption of such systems. In this presentation, we focus on one of the extended reliability metrics, namely resilience to assess the ability of such systems to withstand and recover when hazards occur. We propose quantifications of resilience for non-repairable and repairable systems under multi hazard. As restoration is conducted with limited resource under most circumstances, we recommend importance measures (IMs) to identify critical components in the system.

##### 2 - Resilience Investment in Supply Chain Network Under Stochastic Disruptions

Kedong Chen, University of Minnesota, Minneapolis, MN, 55454, United States,, Ankur Mani, Kevin W. Linderman

Supply chain disruptions are common yet costly. Companies are motivated to invest resilience resource in their supply chain networks to mitigate disruptions, but they face the question of which nodes to invest. This study characterizes the optimal strategies of resilience investment for generic layered supply chain networks. Through analyzing the stochastic network where resilience investment reduces the chance of a node being disrupted, we find node capacity and path characteristics (path length and flow) to be key factors in the investment decision. The frequency of disruptions determines the management focus between node and path. Managerial implications are provided.

##### 3 - Bi-objective Restoration Plan Optimization for Transportation Infrastructures Considering Both Total Travel Time and Unmet Demand

Tingting Zhao, University of South Florida, 4202 E. Fowler Avenue, ENB 118, Tampa, FL, 33612, United States

A bi-objective bi-level problem is formulated for restoration plan optimization of transportation infrastructure system after disruptions. The upper-level one is to maximize system resilience measured by total travel time and unmet demand with limited resources. The lower-level one is a network flow assignment problem considering unmet demand in the system after the event. The single objective problem can be linearized and then transformed to MILP problem. The bi-objective MILP problem is solved by Triangle Splitting Method. The proposed methodology is evaluated with a typical road network.

##### 4 - A Heuristic Approach to the Post-disturbance Microgrid Formation Problem

Xin Shi, Lehigh University, Bethlehem, PA, United States, Kwami Senam A. Sedzro, Alberto J. Lamadrid, Luis F. Zuluaga

Microgrid formation is a potential solution in post-disaster electric grid recovery efforts. Recent works propose distribution level microgrid formation models using MILP techniques. However, these models can only be solved for small and medium-size power systems due to their computational intractability. In this talk, we introduce a heuristic approach that allows to approximately solve the microgrid formation problem for medium to large, more realistic, instances. Furthermore, the proposed approach allows to approximately solve the stochastic version of the problem.

#### 5 - A Stochastic Optimization Model for Road Network Protection and Restoration During a Natural Disaster

Sachin Mhatre, Graduate Assistant, North Carolina Agricultural & Technical State University, 1601, E. Market St., Greensboro, NC, 27411, United States, Xiuli Qu

Natural disasters disrupt infrastructures, communities and thousands of individuals every year in the world. Effective protection and restoration of road transportation systems play an important role in disaster operations, such as rescuing and relief delivery. In this study, a stochastic integer linear programming model is developed to schedule road protection activities and locate road restoration resources when a hurricane approaches, and to plan road restoration activities and allocate resources after a hurricane. The model integrates the decisions for both preparedness and response activities during a disaster, which will improve decision making in disaster management.

### ■ TB08

North Bldg 124A

#### Optimization for Robust and Risk-Aware Learning

Sponsored: Optimization/Nonlinear Programming

Sponsored Session

Chair: Alec Koppel, U.S. Army Research Laboratory, Silver Spring, MD, 20910, United States

##### 1 - Models and Algorithms for Risk-sensitive Inverse Reinforcement Learning

Marco Pavone, Phd, Stanford University, Palo Alto, CA, 94305, United States

The literature on Inverse Reinforcement Learning (IRL) typically assumes that humans take actions in order to minimize the expected value of a cost function, i.e., that humans are risk neutral. Yet, in practice, humans are often far from being risk neutral. In this talk, I will present a framework for risk-sensitive IRL that can explicitly account for a human's risk sensitivity. Specifically, I will present non-parametric and semi-parametric algorithms for inferring a human's underlying risk measure and cost function for a rich class of static and dynamic decision-making settings.

##### 2 - Risk-averse Multi-armed Bandit Problems

Qing Zhao, Professor, Cornell University, 325 Rhodes Hall, Cornell University, Ithaca, NY, 14853, United States, Sattar Vakili

Risk-averse multi-armed bandit problems are studied under the measure of mean-variance. Compared with the risk-neutral objective of maximizing the expected cumulative reward, the mean-variance measure defined on the observed reward process leads to a regret that depends on high-order statistics of the random time spent on each arm and can no longer be written as a simple sum of certain immediate performance loss defined in isolation for each time instant. Regret lower bounds and order-optimal policies are established within both problem-specific and minimax frameworks.

##### 3 - Controlling the Bias-Variance Tradeoff via Coherent Risk for Robust Online Learning with Kernels

Alec Koppel, Phd, U.S. Army Research Laboratory, Adelphi, MD, 20783, United States

In supervised learning, we learn a statistical model by minimizing a merit of fitness averaged over data and ignore the variance, i.e., the gap between the optimal within a hypothesized function class and Bayes Risk. We account for \*both\* by incorporating coherent risk, which quantifies decision uncertainty. We develop the first solution to this problem when in reproducing kernel Hilbert spaces (RKHS) called Compositional Online Learning with Kernels (COLK). COLK uses stochastic quasi-gradient together with greedy projections to mitigate the per-iteration complexity of RKHSs. We establish COLK converges and that its complexity is at-worst finite. Experimentally, COLK overcomes overfitting.

##### 4 - Recursive Optimization of Convex Risk Measures: Mean-Semideviation Models

Dionysios Kalogerias, Postdoctoral Research Associate, Princeton University, Sherrerd Hall Room 119, 98 Charlton Street, Princeton, NJ, 08544, United States, Warren B. Powell

We develop and analyze stochastic subgradient methods for optimizing a new class of convex risk measures, termed as Mean-Semideviations. First, we study the basic properties of Mean-Semideviations, and constructively characterize them from a theoretical viewpoint. We then introduce the MESSAGEp algorithm, a compositional stochastic subgradient procedure for solving convex Mean-Semideviation risk-averse problems to optimality. Pathwise convergence of the MESSAGEp algorithm is established within a new, versatile and powerful theoretical framework, which reveals a fundamental tradeoff between the smoothness of the cost function and that of the particular risk measure of choice.



## ■ TB09

North Bldg 124B

**Nonconvex Optimization in Machine Learning**

Sponsored: Optimization/Nonlinear Programming

Sponsored Session

Chair: Ruoyu Sun, UIUC, Minneapolis, MN, 55414, United States

**1 - Gradient Descent with Random Initialization: Fast Global Convergence for Solving Quadratic Systems of Equations**

Yuxin Chen, Princeton, Yuejie Chi, Jianqing Fan, Yuejie Chi

This talk considers the problem of solving systems of quadratic equations. We investigate the efficiency of gradient descent designed for the nonconvex least squares problem. We prove that under Gaussian designs, gradient descent when randomly initialized yields an  $\epsilon$ -accurate solution in a logarithmic number of iterations given nearly minimal samples, thus achieving near-optimal computational and sample complexities at once. This provides the first global convergence guarantee concerning vanilla gradient descent for phase retrieval, without the need of (i) carefully-designed initialization, (ii) sample splitting, or (iii) sophisticated saddle-point escaping schemes.

**2 - Planning for RL and RL for Planning**

Yuangdong Tian, Facebook, Menlo Park, CA, USA.

Agents trained with reinforcement learning (RL) are usually reactive: they take actions from the observations, perceive new observations and repeat. However, human doesn't behave this way. They plan by predicting what would be possible futures if some actions were taken, and pick the actions that lead to the best consequence. This involves a strong modeling of the world and its dynamics, which is non-trivial to obtain even for simulated situations such as games. In this talk, we introduce our recent works about how planning is done in RL, and how RL can help perform better planning

**3 - Understanding Landscape of Neural Networks for Binary Classification**

Ruoyu Sun, UIUC, IL, United States

We study the landscape of neural networks for binary classification and provide conditions under which the training error is zero at all local minima. We provide a rather comprehensive study on necessary conditions as well as sufficient conditions. For example, we show that while ReLU and sigmoid activations lead to bad local minima, strictly increasing and convex activation functions can eliminate bad local minima. Other conditions include: the neural network should either be single-layered or is multi-layered with a shortcut-like connection, and the surrogate loss function should be a smooth version of hinge loss.

## ■ TB10

North Bldg 125A

**Market Design**

Sponsored: Manufacturing &amp; Service Oper Mgmt

Sponsored Session

Chair: Gabriel Weintraub, Stanford Graduate School of Business, Stanford, CA, 94304, United States

**1 - How (Not) to Allocate Affordable Housing**

Peng Shi, University of Southern California, USC Marshall School of Business, BRI 303D, 3670 Trousdale Pkwy, Los Angeles, CA, 90089, United States, Nicholas A. Arnosti

Motivated by affordable housing allocation in NYC, we study a stylized model in which items are dynamically assigned to waiting agents. The planner has two goals—to match each agent with the most fitting item, and to target the agents with the highest need. We find that the current practice of independent lotteries encourages agents to enter many lotteries, resulting in inefficient matching. The matching can be improved by limiting the number of lottery entries, but this can result in worse targeting. We prove that this tradeoff between matching and targeting cannot be avoided as long as the levels of need are private knowledge, and give guidance on which to prioritize to maximize utilitarian welfare.

**2 - Designing Framework Agreements: A Field Study in Government Procurement**

Marcelo Olivares, Associate Professor, Universidad de Chile, Santiago, Chile, Gabriel Weintraub, Daniela Saban, Eduardo Lara

Framework Agreements (FA) is a commonly used procurement mechanism by governments and large organizations. It is based on an auction-type design to select an assortment of products from multiple suppliers with posted prices, allowing some flexibility and variety to purchasing units. The design of FA requires balancing competition to enter the market with the variety offered inside the market. This paper conducts an empirical study of the FAs used by the Chilean government, identifying inefficiencies in the procurement market, providing improvements to design and conducting a field study to measure the actual effectiveness of the new implemented design.

**3 - Revenue Management versus Machine Learning in Product Assortment: Evidence from Large Field Experiments on Alibaba**

Dennis Zhang, University City, MO, 63124, United States, Jacob Feldman

We developed a personalized multinomial logit model to find the optimal set of products to display for each incoming customer. We deployed our model in Alibaba's online recommendation system and compared its performance against the state-of-art machine learning approach used in Alibaba by conducting a large-scale field experiments over more than 40 million customers. Our results show that, despite its low performance in prediction, the MNL-based approach generates higher revenue per customer.

**4 - Clearing Matching Markets Efficiently: Informative Signals Andmatch Recommendations**

Itai Ashlagi, Stanford University, Huang Engineering Center, 475 Via Ortega, Stanford, CA, 94305, United States

We study how to reduce congestion in two-sided matching markets with private preferences. We show that when the unobservable component of agent preferences satisfy certain natural assumptions, it is possible to recommend potential matches and encourage informative signals such that 1) the market reaches an equilibrium outcome, 2) the overall communication overhead is small. The main idea is to only recommend partners whom the agent has a non-negligible chance of both liking and being liked by, as estimated by the observable component of preferences and prior expression of interest by agents on the other side based on the unobservable component of their preferences.

## ■ TB11

North Bldg 125B

**IFORM SIG**

Sponsored: Manufacturing &amp; Service Oper Mgmt/IFORM

Sponsored Session

Chair: Shawn Mankad, Cornell University, Cornell University

**1 - Credit Risk Propagation Along Supply Chains**

Jing Wu, City University of Hong Kong, Department of Management Sciences, Hong Kong, Senay Agca, Volodymyr O. Babich, John R. Birge

We find that credit risk propagates through multiple supply chain tiers for both positive and negative credit shocks. Specifically, we show sizeable rating and industry-adjusted CDS spread changes of 44-71 bps at the first tier, continuing for 2nd and 3rd tier supply chain partners. Credit risk contagion is more pronounced when supply chain partners are covered by the same analysts. The contagion disappears with inactive supply chain links. The contagion is magnified with longer-term supply-chain relations, trade credit, sales contribution, differentiated products, and customer leverage, while it is moderated when a customer is investment grade or has more inventory.

**2 - Inventory Financing Under Raroc**

Yuxuan Zhang, London Business School, London, United Kingdom, Simin Huang, S. Alex Yang

Starting from the 1990s, banks begin to adopt the Risk Adjusted Return On Capital (RAROC) criterion in loan pricing. In this paper, we study how this criterion influence the bank's decision on inventory financing, as well as the supply chain implication of this pricing mechanism.

**3 - Systemic Risk and Bank Holdings**

Shawn Mankad, Cornell University

The recent financial crisis has focused attention on identifying and measuring systemic risk. We propose a novel approach to estimate the portfolio composition of banks as function of daily interbank trades and stock returns. Our approach estimates bank asset holdings at higher frequencies allowing us to derive precise estimates of (i) portfolio concentration within each bank's measure of diversification and (ii) common holdings across banks's measure of market susceptibility to propagating shocks. We find evidence that systemic risk measures derived from our approach lead, in a forecasting sense, several commonly used systemic risk indicators.

**4 - Regularized Estimation of Factor-augmented Autoregressive Models**

George Michailidis, University of Florida, UF Informatics Institute, 432 Newell Drive, Gainesville, FL, 32611-8545, United States

We consider the factor-augmented vector autoregressive (FAVAR) model in the high dimensions, where the large observed block and the latent factor block jointly follow a vector autoregressive (VAR) model, with an additional information series linked to both of them contemporaneously through a linear model. We address model identifiability and estimation issues and examine the performance of the model through simulations. Further, we apply the model to an economic dataset involving commodity prices and macroeconomic sequences to investigate interlinkages amongst the former.

## ■ TB12

North Bldg 126A

### Crowdfunding

Sponsored: Manufacturing & Service Oper Mgmt

Sponsored Session

Chair: Michael R. Wagner, University of Washington, Seattle, WA, 98195, United States

#### 1 - Signaling to the Crowd: Private Quality Information and Rewards-based Crowdfunding

Soudipta Chakraborty, Duke University, Durham, NC, United States, Robert Swinney

We consider the problem faced by a creator designing a rewards-based crowdfunding campaign via a platform like Kickstarter. The creator solicits pledges from backers, and if total pledges exceed a pre-determined threshold, the campaign is successful, the creator receives all pledges and each backer receives a reward. Otherwise, the campaign fails and backers are refunded their pledges. We determine how the creator should design her crowdfunding campaign when backers know less than her about the value of the reward.

#### 2 - Referral Timing and Fundraising Success in Crowdfunding

Diwakar Gupta, McCombs School of Business, Austin, TX, United States, Gordon Burtch

Entrepreneurs frequently leverage social contacts to generate traffic to a crowdfunding campaign. Considering campaign fundraising progress, we address the question of exactly when an entrepreneur should involve his or her social connections. The optimal strategy depends on whether the rich-get-richer or the crowding-out effect dominates contributor behavior after observing prior capital accumulation. We also report on a number of simulation analyses which speak to heterogeneity in the efficacy of the optimal referral policy under different situations, e.g., in the presence of seed money.

#### 3 - Crowdfunding via Revenue-sharing Contracts

Soraya Fatehi, University of Washington, Michael G. Foster School of Business, University of Washington, 358 Mackenzie Hall, Seattle, WA, 98195-3200, United States

We present a new model of crowdfunding where a platform acts as a matchmaker between a firm needing funds and a crowd of investors willing to provide capital. Once the firm is funded, it pays back the investors using revenue sharing contracts. The firm determines its optimal contract parameters to maximize its expected net present value (NPV), subject to investor participation constraints and platform fees. Parametrized on real data from Bolstr.com, we show that revenue-sharing contracts provide a higher NPV and a lower probability of bankruptcy than equity crowdfunding or a fixed-rate loan, for all levels of cash-flow uncertainty.

#### 4 - Does Crowdfunding Benefit Entrepreneurs and Venture Capital Investors?

Volodymyr Babich, Georgetown University, Washington, DC, United States, Simone Marinesi, Gerry Tsoukalas

We study how crowdfunding interacts with traditional financing sources (VC and bank). We model a multi-stage bargaining game, with a moral-hazard problem between entrepreneurs and banks, and a double-sided moral-hazard problem between entrepreneurs and VCs. Economic value of crowdfunding is generally shared between entrepreneurs and investors, benefiting both. Furthermore, crowdfunding can alleviate underinvestment due to financial frictions problem for some projects. However, crowdfunding can also harm the entrepreneur and the VC. The model provides a theoretical underpinning for recent empirical observations that some projects lose VC financing after successful crowdfunding campaigns.

#### 5 - Crowdfunding, Signaling, and Venture Capital

Jussi Keppo, National University of Singapore, Mochtar Riady Building, BIZ 1 8-69, 15 Kent Ridge Drive, Singapore, 119245, Singapore, Ming Hu, Yunnan Jin

We study how venture capital (VC) investments are affected by crowdfunding platforms. We find that VCs utilize crowdfunding as a signaling device on the quality of startups. Therefore, in industries where the crowdfunding option is available, startups become more strategic and VCs are more likely to delay their investment decisions after observing the information from the crowdfunding platform. We link our findings to VC investment data.

## ■ TB13

North Bldg 126B

### Behavioral OM in Healthcare

Sponsored: Manufacturing & Service Oper Mgmt/Healthcare Operations

Sponsored Session

Chair: Mor Armony, New York University, New York, NY, 10012, United States

Co-Chair: Nan Liu, Boston College, Chestnut Hill, MA, 02467, United States

#### 1 - Load Balancing in Multi-featured Multi-class Multi-skill Service Systems

Nitzan Carmeli, Technion Israel Institute of Technology, Haifa, Israel, Galit B. Yom-Tov, Avishai Mandelbaum

Operational offered load, and its calculated agents utilization through queueing theory, support the design, staffing and routing of congestion-prone service systems. However, in many such systems, and healthcare in particular, agents experience additional features of load such as emotional and cognitive - these cause stress and fatigue even when the offered load is low. How does one balance such load among servers, in a way that accommodates its multi-features? In our research we develop a novel theoretical framework that supports answers to this question. More concretely, we consider a queueing system with skills-based routing, within which we optimally and fairly balance multi-feature load.

#### 2 - Improving the Use of Operating Rooms Using Surgeon Input

Song-Hee Kim, University of Southern California, Los Angeles, CA, United States, Rouba Ibrahim

When allocating operating room times to surgery cases, hospitals need to know how long the surgeries will take. Although the estimation of surgery case duration has been extensively studied, accurately predicting surgery case duration remains a challenge. We examine ways to systematically combine surgeons' forecasts with a model based on observed attributes to improve the accuracy of surgery case duration predictions, and hence the use of operating rooms.

#### 3 - Predicting Readmission Risk by Leveraging Connected Health Devices

Tan Lekwijit, The Wharton School, University of Pennsylvania, 3730 Walnut St, Ste 500, Philadelphia, PA, 19104, United States, Christian Terwiesch, Kevin Volpp

Hospital readmission of patients with chronic diseases is often viewed only as a sign of poor quality of care. However, a significant part of the risk can be attributed to the lack of medication adherence. We utilize daily adherence information obtained from electronic pill bottles and investigate the impact of long-term and short-term medication adherence in patients with coronary artery disease on the risk of readmission. We find that long-term adherence to Statin is associated with a 47% reduction in the likelihood of readmission on any given day. In an ongoing work, we are examining the impact of different levels of adherence interventions, such as messages, calls, and letters, on patient behavior.

#### 4 - Withholding Capacity from Strategic Patients

Yunchao Xu, New York University, New York, NY, 10012, United States, Mor Armony, Nan Liu

Common wisdom suggests that everything else being equal, seeing patients sooner rather than later is preferable. In particular health outcomes improve with reduced delay and so does patient satisfaction. At the same time, if the delay in access to care is reduced, patients may be more inclined not to show up for their appointments given that rescheduling will not result in excessive wait. We investigate how an outpatient care provider should manage capacity in the presence of such strategic behavior of patients. We find that under some circumstances, it is optimal for the service provider to withhold capacity from patients in order to elicit them to show up for their scheduled appointments.

## ■ TB14

North Bldg 126C

**Behavioral Service Operations**

Sponsored: Manufacturing &amp; Service Oper Mgmt/Service Operations

Sponsored Session

Chair: Ilan Lobel, New York University, New York, NY, 10012, United States

Co-Chair: Yash Kanoria

**1 - Managing Customer Churn via Service Mode Control**

Jiaqi Lu, PhD Student, Columbia Business School, New York, NY, 10027, United States, Yash Kanoria, Ilan Lobel

Customer churn is an important issue for service firms. They are expensive to acquire and often leave quickly if disappointed with the service. We formulate an optimal control problem for a firm that needs to dynamically choose between service modes with different risk-reward profiles, faced with a customer that is likely to leave if unhappy with recent experiences. Our results reveal when the firm should deviate from a myopic strategy: prefer a low risk service mode if the customer is currently not a flight risk but may become one if unhappy with the next few services; prefer a high risk service mode if the customer is currently at a flight risk but may no longer be one if happy with the next few services.

**2 - Rewards or Discounts: Improving Fast Food Chain Operations**

Rim Hariss, MIT, Georgia Perakis, Yanchong Zheng

We empirically examine the joint effects of rewards program and price discounts on customer purchase behavior in a fast food chain setting. We use an instrumental variable approach to reliably estimate their joint impact on customer spent and company profit. Leveraging this empirical relationship between reward redemption and purchase on discount, we develop a parsimonious customer choice model to dynamically predict purchase behavior, which allows us to effectively evaluate alternative designs of rewards program and quantify their impacts on profitability. Insights from this analysis are offered to the fast food chain company to help with current efforts on redesigning its rewards program.

**3 - Inconvenience, Liquidity Constraints, and the Adoption of Off-Grid Lighting Solutions**

Bhavani Shanker Uppari, INSEAD, Singapore, Singapore, Serguei Netessine, Ioana Popescu, Rowan Clarke, Manuel Barron, Martine Visser

A significant proportion of world's population does not have access to electricity. Solar-based solutions are usually unaffordable due to consumers' poverty. There are alternative business models relying on rechargeable light bulbs that are sold at a subsidized price and require regular payments for recharges. We investigate the viability of these recharge-based models under poverty. In collaboration with a firm in Rwanda, we collected the bulb usage data from randomized experiments wherein the price and the bulb capacity were varied. We also build a structural model that incorporates the light consumption dynamics, and use it to evaluate theoretically-preferred changes to the existing model.

**4 - Modeling Customer Response to Service Quality Variability with Implications for Pricing**

Jordan Tong, University of Wisconsin, Gregory A. DeCroix

Given the same expected quality, customers tend to demand less when quality is more variable. How should firms price their service in light of this behavior? In a simple setting of repeat service under stationary but variable quality, we show that it is not necessary to model customers with a risk-averse utility function in order to generate a revenue penalty for quality variability. Instead, a simple and behaviorally robust learning-from-experience formulation - even with risk neutrality - can lead to a quality variability penalty. We study the structure of the optimal pricing policy under this relatively understudied mechanism to generate insight into pricing strategy under quality variability.

## ■ TB15

North Bldg 127A

**New Problems in Service Operations**

Sponsored: Manufacturing &amp; Service Oper Mgmt/Service Operations

Sponsored Session

Chair: Georgia Perakis, Massachusetts Institute of Technology, Cambridge, MA, 02142-1347, United States

**1 - Optimizing Objective Functions Determined from Random Forests**

Max R. Biggs, Massachusetts Institute of Technology, 77 Massachusetts Ave NE49-40497, Cambridge, MA, 02139, United States, Rim Hariss

We study the problem of optimizing a tree-based ensemble objective with the feasible decisions in an arbitrary polyhedral set. We model it as a Mixed Integer

Linear Program and show it can be solved to optimality efficiently using Pareto optimal Benders cuts. For large problems, we consider a random forest approximation of only a subset of trees and prove analytical guarantees that this gives rise to near optimal solutions. The error of the approximation decays exponentially as the number of trees increases. We propose heuristics that optimize over smaller forests rather than one large one and showcase their performance on two case studies: a property investment problem and a jury selection problem.

**2 - Picking Multi-item Orders in the Warehouse of a Large Online Retailer: Data, Models and Simulations**

Chongli Daniel Chen, Massachusetts Institute of Technology, Cambridge, MA, 02142, United States, Mehmet Tolga Cezik, Retsef Levi, Georgia Perakis

We describe theoretical and data-driven work in collaboration with an online retailer. In a warehouse, multi-item orders take up capacity on a wall until all items are picked. To avoid exceeding capacity, the retailer must balance picking efficiency with completing orders quickly. We model a novel variant of the Traveling Repairman Problem to account for this tradeoff. We propose a picking policy and determine conditions under which it achieves a greater percentage decrease in order cycle time than the percentage increase in makespan compared to the optimal makespan path, when items lie on a line or grid. We build a data-driven simulation and test our policy, reducing wall utilization by 38%.

**3 - Joint Pricing and Production; A Distributionally Robust Approach**

Qinshen Tang, National University of Singapore, Singapore, Singapore, Georgia Perakis, Melvyn Sim, Peng Xiong

In this paper, we consider a two-period joint pricing and production problem for multiple fashion items. We take distributionally robust approach. By clustering the historical data, we construct a scenario-wise ambiguity set with the support and moment(s) information of the demand. We then reformulate the problem as a tractable MIP problem. Through an extensive numerical study, we get some interesting managerial insights. In particular, we compare policies that arise from different decision rules using various methods for the single (as well as two) product(s) problem.

**4 - The Practice of Bundling Under Competition**

Araz Khodabakhshian, UCLA, Los Angeles, CA, 90024, United States, Guillaume Roels, Uday S. Karmarkar

Bundles are common in many industries, but there are also several examples of firms that choose not to bundle when faced with competition. We study competitive bundling under two models of quantity and price competition. Our analysis shows that even with full symmetry assumptions, competition can give rise to non-symmetric equilibrium strategies among the firms. We study duopoly, as well as, oligopoly bundling and examine the implications of bundling on the entry game. We show equilibrium results given different customer utilities and firm cost structure, covering the full range of strategies for a two product market. Our results have implications for a wide range of service and product industries.

## ■ TB16

North Bldg 127B

**Sustainability in Food and Agricultural Supply Chains**

Sponsored: Manufacturing &amp; Service Oper Mgmt/Sustainable Operations

Sponsored Session

Chair: Yanchong Zheng, Massachusetts Institute of Technology, Cambridge, MA, 02139, United States

Co-Chair: Somya Singhvi, MIT, Cambridge, MA, 02139, United States

**1 - Knowledge Sharing and Learning Among Smallholders in Developing Economies: Implications, Incentives, and Reward Mechanisms**

Shihong Xiao, HKUST, Rm5569, IELM Dept., Clear Water Bay, Kowloon, Hong Kong, 999077, Ying-Ju Chen, Christopher S. Tang

NGOs and governments are advocating various knowledge-sharing platforms for farmers to exchange farming techniques. Putting altruism aside, we examine the overall economic implications for heterogeneous farmers to share their private knowledge voluntarily with others under (implicit) competition. By analyzing a multi-person sequential game, we provide a plausible explanation of why and conditions under which knowledge sharing can be beneficial even when each farmer's profit depends on the total output. We find that the voluntary shared level is inadequate in maximizing farmer welfare, and propose a quota-based reward mechanism that can entice farmers to share more knowledge.



## 2 - Incentive Mechanisms for Managing Hidden Rebates and Deceptive Quotes of a Procurement Service Provider

Xiaoshuai Fan, Hong Kong University of Science and Technology, Kowloon, Hong Kong, Ying-Ju Chen, Christopher S. Tang

When sourcing through a procurement service provider (PSP), the retailer may end up selecting an inefficient manufacturer due to conflicting interests and information asymmetry. PSPs may collect rebates from some willing manufacturers that are “hidden” from the retailer and have incentive to help them win the order by inflating or omitting quotes from those unwilling manufacturers. To reveal PSP’s private information, we explore a deterministic incentive mechanism based on a selection rule and a service fee structure. We show it is Pareto-improving for the retailer and the PSP. Furthermore, when the retailer can penalize the PSP for deceptive quote, we develop a stochastic incentive mechanism.

## 3 - Speculative Shortages in Agricultural Supply Chains: The Effect of Government Interventions

Somya Singhvi, MIT, 235 Albany Street, Cambridge, MA, 02139, United States, Retsef Levi, Yanchong Zheng

Speculative shortages that lead to exorbitant increases in retail prices of essential commodities are a matter of great concern for governments, who employ a range of strategies to mitigate this phenomenon and its impact. We develop analytical models to capture the dynamics of speculative shortages and the impact of government interventions on market behavior and prices. We validate our models using retail price data from India and highlight that to be effective, interventions need to be carefully designed while taking potential strategic responses of market players into account.

## 4 - Impact of Travel Delay in Queues

Wanyi Li, Stanford University, Stanford, CA, United States, Daniela Saban, Erica Plambeck

In service industry, customers have to travel to a server to join the queue. Our project studies the impact of travel delay on queue dynamics in a single server setting. When arrival to queue is not instantaneous, the phenomenon of queue length oscillation may arise. We analyze the welfare impact and waiting time impact that travel delay has on the system. We also identify the parameter regime under which the queue will be stable. We show that oscillation of queue length due to travel delays hurts customer welfare in general. Our theoretical results have important implications on the food processing industry and gives insights on waiting time announcement design in this industry.

## ■ TB17

North Bldg 127C

## Managing Incentives to Improve Performance

Sponsored: Manufacturing & Service Oper Mgmt/Supply Chain

Sponsored Session

Chair: Izak Duenyas, University of Michigan-Ann Arbor, Ann Arbor, MI, 48109-1234, United States

## 1 - Audit and Remediation Strategies in the Presence of Evasion Capabilities

Shouqiang Wang, The University of Texas at Dallas, Naveen Jindal School of Management, 800 W. Campbell Rd, Richardson, TX, 75080, United States, Francis E. De Vericourt, Peng Sun

Firms often face negative externalities from privately observable stochastic events that occur at another party. To mitigate these externalities, the firm needs to know in time if such an event has occurred and hold the other party liable. The other party, however, prefers to conceal the event’s occurrence so as to evade its responsibility. The goal of this paper is to devise efficient strategies for firms to uncover the occurrence of stochastic events such as these.

## 2 - Procurement Mechanisms with Post-auction pre-selection Cost-reduction Investigations

George Chen, London Business School, London, United Kingdom, Damian Beil, Izak Duenyas

Consider the following procurement setting: After seeing suppliers’ bids, the buyer can choose to investigate some suppliers to identify cost-reduction opportunities; the investigated suppliers’ costs will decrease by the identified cost-reductions; the buyer then awards the contract. We characterize the optimal first-price sealed-bid mechanism, as well as an optimal mechanism among a wider class of mechanisms. For ex-ante symmetric suppliers, incorporating investigations create an ex ante win-win situation for everyone. The win-win may break down when suppliers are sufficiently asymmetric, but no supplier has the incentive to unilaterally block investigation.

## 3 - Optimal Contract for Machine Repairing and Maintenance

Feng Tian, University of Michigan, 2231 Stone Road, Ann Arbor, MI, 48105, United States, Peng Sun, Izak Duenyas

A principal hires an agent to repair a machine when it is down and maintain it when it is up. If the agent exerts effort, the downtime is shortened, and uptime is prolonged. The effort, however, is costly to the agent and unobservable to the principal. The principal intends to design the optimal dynamic contract, which involves payments and contract termination, to induce the agent to always exert effort. We formulate this problem as a stochastic optimal control model with incentive constraints in continuous time over an infinite horizon. Although we allow payments to take general forms to depend on all past public information, the optimal contract has a simple and intuitive structure.

## ■ TB18

North Bldg 128A

## Networks, Matching and Platforms

Emerging Topic: Business Model Innovation

Emerging Topic Session

Chair: Yiangos Papanastasiou, University of California Berkeley, Berkeley, CA, 94720, United Kingdom

## 1 - Dynamic Allocation Without Money: An Equivalence Result

Nicholas A. Arnosti, Columbia Business School, 3022 Broadway, Uris Hall rm 402, New York, NY, 10027, United States

We consider a large-market model in which objects of different types are dynamically assigned to waiting agents, who have arbitrary preferences over object types. We find that using independent lotteries is equivalent to using a single waitlist in which applicants lose their position after rejecting an offer. Furthermore, these systems are equivalent to clearing the market with virtual currency. Finally, we show that using multiple waitlists is equivalent to using a single waitlist in which applicants are allowed to keep their position after rejecting an offer.

## 2 - Market for Personal Data?

Azarakhsh Malekian, University of Toronto, 35 Oak St., Somerville, MA, 02143, United States

With the increasing ease with which personal information can be accessed, the issue of privacy has become central for the functioning of various online platforms. In this talk, we study the privacy implications of market design for personal information.

## 3 - Platforms for Socially Responsible Operations

Daniela Saban, Stanford University, Palo Alto, NY, 94304, United States

Implementing socially responsible operational practices is becoming a priority for most organizations. Online platforms, if carefully designed, can be effective tools to implement such practices. We discuss two examples: a platform to increase transparency in government purchases (joint work with R. Beer and I. Rios), and a platform to increase traceability in the palm oil supply chain (joint work with S. Camelo, J de Zegher, and D. Iancu)

## 4 - When Bribes are Harmless: The Power and Limits of Collusion-resilient Mechanism Design

Artur Gorokh, Cornell University, Ithaca, NY, United States, Siddhartha Banerjee, Krishnamurthy Iyer

Many results in mechanism design break down when participating agents can collude. In particular, when monetary transfers are allowed between colluding agents, truthful revelation and efficiency are incompatible. We consider a relaxation for the problem, replacing truthful revelation with a property we call collusion dominance: all coalitions need to have dominant strategies. We prove an efficient, collusion-dominant mechanism exists for a large class of allocation problems that satisfy a surplus submodularity condition, and conversely, prove impossibilities when this condition fails.

## ■ TB19

North Bldg 128B

**New Directions in Pricing and Revenue Management**

Sponsored: Revenue Management &amp; Pricing

Sponsored Session

Chair: Georgia Perakis, Massachusetts Institute of Technology, Cambridge, MA, 02142-1347, United States

**1 - Estimating Customer Trends to Target Promotions**

Lennart Baardman, Massachusetts Institute of Technology, Cambridge, MA, 02139, United States, Setareh Borjani Boroujeni, Tamar Cohen, Kiran V. Panchamgam, Georgia Perakis

Detecting trends in fashion can help retailers determine effective personalized promotion plans more easily. Social media data is valuable in understanding these trends, but it is often unavailable. We introduce a personalized demand model that captures customer trends from transaction data instead. We base our efficient estimation method on instrumental variables, which allows us to draw causal inference on the effects that targeted promotions have. The promotion targeting problem is NP-hard to solve, so we develop an efficient and provably-good greedy approach. Finally, with real fashion retail data, we estimate our customer trend model and test the promotion targeting algorithm.

**2 - Dynamic Pricing for Unknown Latent Class Models**

Divya Singhvi, MIT, 235 Albany Street, 5010 A, Cambridge, MA, 02139, United States, Pavithra Harsha, Georgia Perakis

We consider the problem of dynamic pricing when customers belong to unknown latent classes. Specifically, we consider a demand model in which a customer's demand response depends on her class. Neither the class, nor the demand functions of the customer class is known. We construct a dynamic pricing policy that is asymptotically optimal and show that it performs considerably better than other benchmark policies for the latent class case.

**3 - Dynamic Learning and Optimization for Online Advertising Portfolios Under Periodic Budgets**

Elaheh Fata, Massachusetts Institute of Technology, Cambridge, MA, 02139, United States, Lennart Baardman, Georgia Perakis, Abhishek Pani

The tremendous growth in online personalized data and ad channels enables publishers to auction off targeted advertising slots to advertisers. Everyday, advertisers bid on a portfolio of targets to maximize advertising revenue within their budget constraint. As the advertiser needs to learn the value of targets, we use an exploration-exploitation framework to model this online advertising portfolio optimization problem. We solve this problem using an optimistic-robust learning (ORL) algorithm based on UCB algorithms and robust optimization. Theoretically, we prove its expected regret is bounded, and computationally, we show its powerful performance on real-world data.

**4 - Markdown Policies for Demand Learning and Strategic Customer Behavior**

N. Bora Keskin, Duke University, Fuqua School of Business, 100 Fuqua Drive, Durham, NC, 27708-0120, United States, Hongfan Chen

We consider a firm selling a product to a finite population of myopic and strategic customers with heterogeneous valuations. The firm faces uncertainty about the market size and how strategic customers are. We develop guidelines for designing asymptotically optimal markdown policies for demand learning in the presence of strategic customers.

## ■ TB20

North Bldg 129A

**Revenue Maximization Beyond Traditional Models**

Sponsored: Revenue Management &amp; Pricing

Sponsored Session

Chair: Emmanouil Pountourakis, University of Texas at Austin, Austin, TX, United States

**1 - Selling Partially-ordered Items: Exploring the Space Between Single- and Multi-dimensional Mechanism Design**

Kira Goldner, University of Washington, Box 352350, Seattle, WA, 98195, United States

With respect to optimal seller revenue, the single-dimensional (i.e. one item) setting and multi-dimensional (i.e. heterogeneous items) setting sit at extreme ends of a spectrum: from simple and fully characterized (single-dimensional) to complex and nebulous (multi-dimensional). In this paper, we study where various bundles of items are for sale, and a buyer is single-minded for some bundle (i.e. is satisfied if and only if he receives a superset of said bundle). We prove that this setting's optimal mechanism sits between the above extremes, both in menu size (here it is unbounded, but always finite) and in the known

characterization (here we give structural properties, but it is not closed-form).

**2 - Optimal Mechanism Design with Risk-loving Agents**

Emmanouil Pountourakis, University of Texas at Austin, Austin, TX, United States, Evdokia Velinova Nikolova, Ger Yang

One of the most celebrated results in mechanism design is Myerson's characterization of the revenue optimal auction. However, this result relies heavily on the assumption that buyers are indifferent to risk. In this paper we study the case where the buyers are risk-loving, i.e. they prefer gambling to deterministic rewards. We characterize the optimal auction and show that randomization can be used to extract more revenue than when buyers are risk-neutral. Most importantly, we show that the optimal auction is simple: the optimal revenue can be extracted using a randomized take-it-or-leave-it price for a single buyer and using a loser-pay auction, a variant of the all-pay auction, for multiple buyers.

**3 - Algorithmic Delegation**

Ali Khodabakhsh, University of Texas at Austin, Austin, TX, United States, Emmanouil Pountourakis, Sam Taggart

We initiate the study of delegation from an algorithmic perspective. An uninformed principal must consult an informed agent to make a decision over which both agent and principal have preferences that depend on the state of the world. The principal may commit to a mechanism, mapping agent's reports to actions. We derive measures of alignment and conflict between the principal and agent for each action in each state, and show that when alignment is insensitive to the state, it is optimal for the principal to select an action without consulting the agent. When conflict is insensitive to the state, it becomes approximately optimal for the principal to adopt a form of threshold policy.

**4 - On Low-rank (quasi-convex) Minimization for a Wide Class of Combinatorial Problems**

Orestis Papadigenopoulos, University of Texas at Austin, Austin, TX, 78705, United States, Swati Gupta, Evdokia Velinova Nikolova

The problem of non-linear, low-rank discrete minimization has been studied under the following similar assumptions: (a) the optimal solution lies on the Pareto-optimal front of a corresponding multi-objective optimization problem, or (b) the objective function is quasi-concave. In our attempt to relax these assumptions, we study minimization of quasi-convex objectives over combinatorial sets and propose efficient approximation schemes. Note that our problem is already NP-hard, even for the case where the rank of the quasi-convex objective is one, using a simple reduction from the exact spanning tree problem.

## ■ TB21

North Bldg 129B

**Topics in Revenue Management and Assortment Optimization**

Sponsored: Revenue Management &amp; Pricing

Sponsored Session

Chair: Pelin Pekgun, University of South Carolina, Columbia, SC, 29205, United States

Co-Chair: Ovunc Yilmaz, University of Notre Dame, South Bend, IN, 46617, United States

**1 - Multi-location Assortment Optimization under Capacity Constraints**

Alper Sen, Bilkent University, Department of Industrial Engineering, Bilkent, Ankara, 06800, Turkey, Basak Bebitoglu, Philip Kaminsky

We study the assortment optimization problem of a retailer which uses multiple DCs to fulfill orders. Each DC can carry up to a pre-specified number of products and is responsible for a region whose customers' choice is governed by an MNL model. A DC can fulfill demand from another region, but at an additional cost. The retailer's problem is to determine the products carried in each DC and the assortment in each region so as to maximize its expected profit. We show that the problem is NP-complete and develop a conic MIP formulation. Numerical experiments show that large instances can be solved optimally using this approach. Finally, we study the effect of various factors on profits and assortment structure.

**2 - Finite-horizon Approximate Linear Programs for an Infinite-horizon Revenue Management Problem**

Fan You, University of Colorado-Boulder, 995 Regent Drive, Boulder, CO, 80302, United States, Thomas Vossen, Dan Zhang

We consider a rolling-horizon revenue management problem that is formulated as an infinite-horizon discounted cost Markov decision process. We propose a solution strategy based on approximate linear programming. Under affine and finite-horizon approximations, we show that the approximate linear programming formulations admit compact representations and therefore can be solved efficiently. The solutions provide revenue bounds and can be used to construct heuristic control policies. We conduct numerical study to evaluate bound and policy performance.

**3 - Correcting for Price Endogeneity in Demand Models:****Linear Regression v. Discrete Choice**

Stacey Mumbower, University of South Carolina, 1014 Greene Street, Columbia, SC, 29208, United States, Pelin Pekgun, Mark Ferguson

The combination of capacity controls and price changes in the airline industry results in fares that are heavily influenced by demand signals, leading to price endogeneity in demand models. Using an airline dataset to model flight-level demand as a function of daily prices, we demonstrate and compare two modeling approaches where price endogeneity can be corrected with instrumental variables. More specifically, we compare a linear regression modeling methodology to a discrete choice methodology and compare price elasticity estimates from both models. We highlight several key differences between the two approaches and discuss challenges that researchers encounter in model estimation.

**4 - A Product-focused Approach to Dynamic Programming Decomposition for the Network Revenue Management and Pricing Problems**

Ravi Kumar, PROS Inc, Houston, TX, United States, Wei Wang, Dariusz Walczak

We consider a dynamic programming formulation of the network revenue management problem. Due to the curse of dimensionality, various approximate dynamic programming methods based on the classical resource-based decomposition approach are used in practice. We revisit our earlier alternative idea of the product-based network decomposition and develop a novel dynamic model for the problem that relies on simultaneous solving of sub-problems. We present numerical analysis to compare the revenue and computation performance of the new method with the more classical ones.

**■ TB22**

North Bldg 130

**On-Demand Transportation Services**

Sponsored: Revenue Management & Pricing

Sponsored Session

Chair: Philipp Afeche, University of Toronto, Toronto, ON, M5S 3E6, Canada

Co-Chair: Costis Maglaras, Columbia University, New York, NY, 10027, United States

**1 - Ride Solo or Pool: The Impact of Sharing on Optimal Pricing of Ride-sharing Services**

Jagan Jacob, University of Rochester, Simon Business School, 4-349 Carol Simon Hall, Rochester, NY, 14627, United States, Ricky Roet-Green

Using on-demand ride-sharing service providers (RSPs) such as Uber and Lyft, passengers can either ride solo and pay full fare, or share the ride with a fellow passenger (pooling) and pay a reduced fare. Though pooling is less expensive, cost of sharing is incurred from sharing the space with a possible stranger. We use stochastic modeling to study the passengers' ride-choices at equilibrium, the RSP's revenue-maximizing pricing strategies, the impact of the number of cars available, and social welfare.

**2 - Economic Challenges in Designing a Sustainable Urban Mobility Marketplace**

Ragavendran Gopalakrishnan, Postdoctoral Associate, Cornell University, Ithaca, NY, United States, Chamsi Hssaine, Siddhartha Banerjee, Samitha Samaranayake

Mobility-as-a-Service is becoming increasingly more efficient, convenient, and ubiquitous in urban areas, with the proliferation of multiple service providers across several modes. Instead of private service providers operating independently, a centralized marketplace in which they participate along with a public transit agency to collectively clear demand using multi-modal trips would enjoy a better operational efficiency, by increasing the quality of the mobility solutions offered to commuters. In this talk, we discuss the challenging task of finding an efficient mechanism/contract structure that would stabilize such a centralized mobility marketplace from an economic perspective.

**3 - Fairness of Pricing and Service Priority in Last Mile Transportation Systems**

Yiwei Chen, University of Cincinnati, Cincinnati, OH, United States, Hai Wang

We consider a last-mile transportation system (LMTS) that consists of regular-type passengers and special-type passengers, such as senior. A special-type passenger who has a higher valuation of service usually has a lower waiting disutility. We show that with the objective of maximizing profit or social welfare, the LMTS operator always has incentive to give the special-type passengers the least service priority and charge them more than the regular-type passengers. This entails the necessity to impose fairness constraints on the price discount and service priority for the special-type passengers. We use real data in Singapore transportation system to quantify the analysis.

**4 - A Tale of Timescales: Surge Pricing and Matching for Hotspot Demand Shock in Ride-Hailing Networks**

Zhe Liu, Columbia Business School, 3022 Broadway, New York, NY, 10027, United States, Philipp Afeche, Costis Maglaras

We study a ride-hailing network that matches price- and delay-sensitive riders with strategic drivers. We consider surge pricing and spatial matching in response to an uncertain demand shock at a hotspot. We characterize optimal centralized and decentralized policies, and show how their performance depends on three key timescales, rider patience, shock duration, and drivers' travel delay to the hotspot.

**■ TB23**

North Bldg 131A

**Financial Risk Management**

Sponsored: Finance

Sponsored Session

Chair: Christoph Frei, University of Alberta, Edmonton, AB, T6G 2G1, Canada

Co-Chair: Abel Cadenillas, University of Alberta, Edmonton, AB, T6G 2G1, Canada

**1 - Bail-ins And Bailouts: Incentives, Connectivity, and Systemic Stability**

Benjamin Bernard, University of California, Los Angeles, 1440 Veteran Ave, Unit 344, Los Angeles, CA, 90024, United States, Agostino Capponi, Joseph E. Stiglitz

We develop a framework for analyzing how banks can be incentivized to make contributions to a voluntary bail-in consortium. At the heart of the issue lies the credibility of the regulator's threat to not bail out insolvent banks when no solvent bank agrees to contribute. We show that credible bail-in strategies exist if and only if the network hazard does not exceed a certain threshold. The threat is more credible and incentive-compatible contributions by banks are larger in more concentrated networks, making more them more desirable in the presence of bail-ins than more diversified networks.

**2 - The Optimal Government Debt Ceiling When Interventions Are Bounded**

Abel Cadenillas, University of Alberta, Department of Mathematical Sciences, Edmonton, AB, T6G 2G1, Canada

We develop a government debt management model to study the optimal government debt ceiling when the ability of the government to generate primary surpluses to reduce its debt ratio is bounded. We obtain an analytical solution for the optimal debt ceiling. [This is a joint work with Ricardo Huaman-Aguilar].

**3 - Contracting For Financial Execution**

Christoph Frei, University of Alberta, Mathematical and Statistical Sciences, CAB 621, Edmonton, AB, T6G 2G1, Canada, Markus Baldauf, Joshua Mollner

Financial contracts often specify reference prices whose values are undetermined at the time of contracting, which introduces the possibility that one side manipulates them to the detriment of the other. Motivated by this, we study a model of financial contracting with the potential for manipulation of this nature, finding that a simple contract based on the volume-weighted average price (VWAP) emerges as uniquely optimal solution to a principal-agent problem between a client and her broker. This result explains the popularity of guaranteed VWAP contracts in equity trading and suggests a direction for improvement upon the status quo in other asset classes.

**4 - Real Options With Performance-sensitive Debt**

Benoit Chevalier-Roignant, King's College London, 30 Aldwych, London, London, WC2B 4BG, United Kingdom, Alain Bensoussan, Alejandro Rivera

We consider a firm that decides on when and by how much to expand its production capacity. This firm is not financed solely by equity, but also by a performance-sensitive debt (PSD) instrument (Manso, Strulovici and Tchisti, 2010). Debt financing induces here the possibility for shareholders—to which benefits the management decides—to default on their debt obligations (Leland, 1994). We investigate the interactions between the performance-sensitive coupon and the firm's capacity expansion strategy as well as the extent to which PSD can mitigate the underinvestment problem on both the timing and sizing of the investment.



## ■ TB24

North Bldg 131B

**Value Brought by Digital Transformation**

Sponsored: EBusiness

Sponsored Session

Chair: Lu Yan, Indiana University, Bloomington, IN, 47401, United States

**1 - Users' Continuous Participation in the Online Weight-loss Communities**

Tongxin Zhou, University of Washington, 3927 Adams Lane NE, Seattle, WA, 98105, United States, Lu Yan, Yingfei Wang, Yong Tan

Many weight-loss communities are designed to provide individuals with community support and, thus, help with their weight management. However, it has been noticed that such communities suffer from high drop-out rate. Therefore, we are interested in finding what factors influence users' continuous participation. We adopt the Continuous-time Hidden Markov model to calibrate users' participation trend. The hidden state we modeled is users' commitment to weight-loss. We find that self-monitoring tools are effective for users with low commitment level. Social support tools such as friend and supporter functions exert different effects on users with different commitment levels.

**2 - To Mine or Not to Mine: An Analysis of Crypto-mining Profitability**

Vipul Aggarwal, University of Washington, Seattle, WA, 98105, United States, Yong Tan

In the cryptocurrency ecosystem, miners wield an inordinate amount of power as their participation can stagnate or extend a blockchain. Miners' participation is incentivized through block fees and rewards subject to finding the right hash value at some given difficulty level. We investigate their mining preferences after the Bitcoin fork of August 2017 which resulted in the creation of Bitcoin cash (BCH). Due to fluctuation in difficulty levels of BCH, miners move frequently between the chains. However, profitability ratios do not justify such frequent movements in the face of competition from other miners. We analyze their mining behavior using a structural model to ascertain their motivations.

**3 - Adaptive and Personalized Thermal Comfort Based HVAC Control**

Weilong Wang, Purdue University, 403 W. State Street, West Lafayette, IN, United States, Siliang Lu, Chaochao Lin

Throughout a person's whole life, he/she spends 90% of time indoors since buildings can provide satisfactory environments for human beings. As one of the key building systems, Heating, ventilation and air-conditioning (HVAC) system plays a key role in shaping the building performances. The effective and efficient HVAC operations not only achieve energy savings but also create a more comfortable environment for occupant indoors. We use Machine Learning technology to analyze differences of thermal sensation under the same conditions between different people with GMM clustering and then implement value iteration-based controller with the prediction model as the simulated environment.

**4 - The Substitution Effect of Sharing-bike on Ride-sharing Platform**

Juan Qin, Harbin Institute of Technology, 4138 Brooklyn Ave NE, WA 98105, Seattle, WA, 98105, United States

Sharing-bike was introduced to solve the "last-mile problem" whereas ride-sharing platform has been serving as a popular means for both short-distance and long-distance journeys. Does sharing-bike solve the "last-mile problem" and have a substitution effect on ride-sharing platform? Will geographic heterogeneity affect the way sharing-bike and ride-sharing platform compete? We take a natural experiment setting and conduct an RDD model to answer these research questions. We exploit granular order data from a leading ride-sharing platform in China and combine it with geographic information to look into the heterogeneous substitution effect.

## ■ TB25

North Bldg 131C

**Best Student Paper Competition – IV**

Sponsored: Service Science

Sponsored Session

Chair: Aly Megahed, IBM Research-Almaden, San Jose, CA, 95123, United States

**1 - Service Science Best Student Paper Competition**

Aly Megahed, IBM Research - Almaden, San Jose, CA, 95123, United States

This session consists of finalists presentations (judged by an expert panel) to determine the Best Student Paper Award for the Service Science Cluster.

## ■ TB26

North Bldg 132A

**E-commerce**

Sponsored: Service Science

Sponsored Session

Chair: Irfan Kanat, Ohio University, 123 Louise Lane, Athens, OH, 45701, United States

**1 - A New Lp (0<p<1) Distance-based Similarity Measure for Collaborative Filtering to Preserve Item-wise Independence**

Shan Jiang, North Carolina State University, 1513 Collegeview Avenue, Unit 101, Raleigh, NC, 27606, United States, Shu-Cherng Fang, Qi An, Zheming Gao

In the field of recommendation systems, neighborhood-based collaborative filtering is one widely accepted method of making recommendations. The first and most crucial step of this method is to measure similarities between customers so that recommendations to a target user can be made based on the information from similar past users. In this paper, we propose an lp-distance-based similarity measure with  $0 < p < 1$ , which makes better use of rating values and is resistant to biases from some items. Numerical results show that the proposed similarity measure is able to generate more accurate predictions with general sparsely distributed datasets as well as with datasets having cold start conditions.

**2 - A Deep Choice Model for Hiring Prediction in Online Labor Markets**

Yixuan Ma, Beijing Jiaotong University, Beijing, China, Zhenji Zhang, Alexander Ihler

The fast-flouring online labor markets provide valuable opportunities to study hiring mechanism. We construct a relational dataset composed of 722,339 accomplished job posts that are tendered by multiple bidders from one of the largest real-world freelancer platform. We propose a Deep Choice Model (DCM) that extends the classical Conditional Logit Model (CLM) to learn the non-linear utility functions for hiring decision making. The DCM can be well-fitted in modern Deep Neural Network framework and be implemented using  $1 \times 1$  convolutional networks. We test the DCM on the 12 categories of job posts in the constructed dataset. Results show that the DCM outperforms the CLM.

**3 - Digital Goods Market Share as a Growth Problem**

Irfan Kanat, Assistant Professor, Ohio University, 123 Louise Lane, Athens, OH, 45701, United States

The market share of digital goods follow a distinct pattern. The market share grows rapidly for a short period after release, the growth first slows and then stops after a period. The exact shape of the growth curve is driven by product design, and promotions employed by the developer. Nature of digital goods (marginal cost, ownership structure, repeat purchases) create significant differences in the growth structure in comparison to more traditional physical goods, meriting a closer inspection. In this study we investigate the effects of product design and promotions on growth of market share utilizing a unique dataset obtained from one of the most popular digital distribution platforms (Steam).

**4 - Dynamic Pricing of New Products under Anticipatory Adoption Models**

Mehrnaz Amjadi, PhD Student, UIC College of Business, 601 S. Morgan St, UH2401, Chicago, IL, United States, Vijay Kamble, Theja Tulabandhula

Adoption of services or products is a critical concern for new businesses. Many of these products/services are characterized by strong network effects, i.e., an individual's utility for adoption depends on the total number of people who have adopted (e.g., Waze). From the perspective of a potential buyer, her decision of adoption thus depends on her speculated adoption level in the market, which is typically marked by uncertainty. In this work, we investigate the role of dynamic pricing in temporally controlling this uncertainty in the market in order to maximize the firm revenue.

## ■ TB27

North Bldg 132B

**Publishing in INFORMS Transactions on Education**

Sponsored: Education (INFORMED)

Sponsored Session

Chair: Jeroen Belien, KU Leuven, Brussel, 1000, Belgium

**1 - Publishing in Inform Transactions on Education**

Jeroen Belien, KU Leuven, Warmoesberg 26, Brussel, 1000, Belgium

The panelists include ITE editors and authors who have published recently in ITE. The authors will discuss their experiences with submitting articles to ITE. The editors will provide suggestions to authors who wish to submit their work to ITE; in particular, articles about case studies, educational games and puzzles.

**Panelists**

Dries Goossens, Ghent University, Tweeckerkenstraat 2, Gent, 9000, Belgium  
 Stefan Creemers, IESEG France, Lille, France  
 Margret V. Bjarnadottir, Breidavik 87, Reykjavik, 112, Iceland  
 Julie Ann Williams, University of West Florida, Pensacola, FL, United States

**■ TB28**

North Bldg 221A

**Joint session RAS/TSL: Intermodal**

Sponsored: Railway Applications

Sponsored Session

Chair: Mike D. Prince, BNSF Railway, Fort Worth, TX, 76244, United States

Co-Chair: Justin Goodson, Saint Louis University, St. Louis, MO, 63108, United States

**1 - Opportunities for Optimization and Automation in Intermodal Terminal Operations**

Steven Jay Tyber, General Electric, Chicago, IL, 60613, United States

The recent surge in intermodal volumes and truck driver shortage has pushed many rail terminals to their limits. In this talk, we survey the challenges faced by intermodal terminals and discuss the central role optimization and automation will play in driving operational efficiency and improved utilization of limited physical real-estate.

**2 - The Role Of Partial Information And Commitment In Dynamic Transportation Procurement**

Pol Boada-Collado, Northwestern University, Evanston, IL, United States, Karen Smilowitz, Sunil Chopra

We analyze decision processes related to commitment contracts in transportation procurement. We consider a novel setting motivated by industry with short-term demand visibility, adding additional dynamism. We model the decision process of selecting transportation modes when partial information is available and show how partial information fundamentally changes contracting policies.

**3 - Investigating the Capacity of Different Intermodal Terminal Layouts with AnyLogic**

Wesley Chen, University of Illinois Urbana-Champaign, 205 N. Mathews, Graduate Center, Urbana, IL, 61801, United States

Freight railways in the United States are currently transporting record volumes of containers and trailers in intermodal service. An efficient and reliable network of intermodal trains requires inland intermodal transloading facilities with sufficient capacity to handle growing traffic volumes. In this research, AnyLogic simulation is used to examine different terminal layouts and operating factors and their relationship to the overall capacity of an intermodal terminal.

**4 - Appointment Scheduling for Intermodal Dray Operations**

Lisa Tang, Schneider, Green Bay, WI, 54313, United States

Effective Appointment Setting (AS) is a key influencer in the success metrics of intermodal operations. While the primary objective of successful AS is to facilitate productive routing options for the subsequent driver dispatch process, decisions made at this level also impact other profit measures, such as driver capability for new order acceptance and ramp dwell. In this session, we will discuss Schneider's network model approach to providing optimal appointment suggestions, which takes into account shipment forecast, empty miles, ramp dwell and driver schedules. We will also review how model output can be used to provide feedback on driver capability.

**■ TB29**

North Bldg 221B

**Mobility on Demand Systems with Transit Integration**

Sponsored: TSL/Urban Transportation

Sponsored Session

Chair: Samitha Samaranyake, Cornell University, Ithaca, NY, 14853, United States

**1 - On-demand Multimodal Transit Systems: A Case Study**

Pascal Van Hentenryck, University of Michigan, 1813 IOE Building, 1205 Beal Avenue, Ann Arbor, MI, 48108-2117, United States

This talk describes the design and operations of an on-demand multimodal transit systems, combining different fleets of vehicles. A case study for the city of Ann Arbor is presented and offers key insights on a potential future for transit agencies.

**2 - On the Interaction between Autonomous Mobility-on-Demand and Public Transportation Systems**

Marco Pavone, Stanford University, Stanford, CA, United States

In this talk I will discuss models and algorithms to integrate autonomous mobility-on-demand systems with public transportation. In particular, I will discuss the design of socially-optimal control policies, present a real-world case study for New York City, and discuss a number of opportunities for future research.

**3 - Operational Challenges of using On-Demand Services as a First/Last Mile Solution – Some Insights from Ford**

Crystal Wang, Ford Motor Company, Detroit, MI, United States

Some city agencies are interested in integrating On-Demand service for the first/last mile solution and Mass-Transit for the rest of the trip. However, this solution does not work for all cities. We will present the simulation results of On-Demand first/last mile solution for different city types. On the other hand, Ford implemented On-Demand service for first/last mile solution in Shanghai in 2016. We will talk about some interesting observations and real challenges from this pilot, and encourage researchers for further investigation.

**4 - Integrating Mobility-on-demand Services with Mass Transit**

Samitha Samaranyake, Cornell University, School of Civil & Environmental Engineering, 220 Hollister Hall, Ithaca, NY, 14853, United States

While ride-hailing services provide a valuable service, as evident by their popularity, there are many questions regarding their scalability, efficiency, equity and externalities (e.g. congestion, pollution etc.). For these systems to be a comprehensive mobility solution, they need to be better integrated with higher capacity services such as mass-transit. Operationalizing such a system requires the ability to efficiently match riders across multiple services in real time, a computationally challenging task to solve at an urban scale. We present some models for operating such a multi-modal on-demand service and discuss some of the computational challenges including hardness results.

**■ TB30**

North Bldg 221C

**Joint Session Smart Cities/MIF: Energy Aspects Towards a Smart City**

Emerging Topic: Smart Cities

Emerging Topic Session

Chair: Krystel Castillo, University of Texas-San Antonio, San Antonio, TX, 78249, United States

**1 - Optimal Sizing and Stochastic Control of a Micro-Grid Using Behind-the-meter Battery Storage and Photovoltaic Panels**

Ying Chen, PhD, UTSA - Texas Sustainable Energy Research Institute, San Antonio, TX, 78249, United States, Krystel Castillo, Bing Dong

We present an efficient building energy management system installed with a behind-the-meter battery energy storage (BES) system and photovoltaic panels. In this micro-grid system, BES system as a buffer is used to alleviate the stochastic nature from the solar energy and dynamic short-term demands from the building. In this study, we use wait-and-see idea from stochastic programming with the martingale model of forecast evolution method to achieve the averaged optimal battery size and power trading limit for this system. And then, we use myopic and lookahead policies with deterministic forecasts and stochastic forecasts to implement the control for this sequence problem, respectively.

**2 - A Simulation Approach to Allocating Microgrid Generation for Resilience Against Extreme Weather**

Tongdan Jin, Texas State University, 601 University Drive, Ingram School of Engineering, San Marcos, TX, 78666, United States, Priyadharshini Kumaravelan, Honggang Wang

Microgrid has the capability of enhancing grid resilience through defensive operations in contingency. We present a simulation model for designing resilient distribution network via distributed wind and solar integration. We strive to achieve three performance goals manifested as prevention, survivability and recovery.

**3 - Blockchain-Assisted Crowdsourced Energy Systems**

Ahmad F. Taha, PhD, The University of Texas at San Antonio, San Antonio, TX, 78249, United States

Crowdsourcing relies on people's contributions to meet certain objectives. This work explores a framework for Crowdsourced Energy Systems (CES), where small-scale energy generation or energy trading is crowdsourced from distributed energy resources. An operational model for CESs with different types of crowdsources is proposed. The model yields market equilibrium depicting distributed generation setpoints. Crowdsourcing incentives are designed to steer crowdsources to the equilibrium. As the number of crowdsources/transactions scales up, a secure energy trading platform is required. To that end, the presented research is integrated with a lightweight blockchain implementation.

#### 4 - A Two-stage Design and Analysis of Computer Experiments Approach for Optimizing a System of Electric Vehicle Charging Stations

Victoria C.P. Chen, The University of Texas at Arlington, Industrial, Manufacturing, & Systems Engr., Campus Box 19017, Arlington, TX, 76019-0017, United States, Ukesh Chawal, Jay Michael Rosenberger

A two-stage framework is developed to address the design of a system of electric vehicle (EV) charging stations. The first stage specifies the design of the system that maximizes expected profit. Profit incorporates costs for building stations and revenue evaluated by solving a system control problem in the second stage. The control problem is formulated as an infinite horizon, continuous-state stochastic dynamic programming problem. To obtain a system design solution using our two-stage framework, we propose an approach based on design and analysis of computer experiments (DACE).

#### 5 - Decision Analytic Framework for Evaluating Future Power Generation Pathways

Thushara De Silva, PhD Candidate, Vanderbilt University, 105 Jefferson Square, Nashville, TN, 37215, United States, George M. Hornberger, Hiba Baroud

Power generation planning objectives are reliable power system, economic efficiency, environmental sustainability, and social acceptability. Multiple alternatives, consists of different technologies and resources, must be assessed in multiple objectives. The objective of this study is to develop a multicriteria decision analysis model to select a power generation pathway for Sri Lanka by developing different alternative pathways, examining them across multiple objectives, and incorporating preferences of multiple stakeholders. A pathway; mix of renewable and fossil fuel resources aimed at achieving energy security can meet multiple criteria associated with future power generation.

## ■ TB31

North Bldg 222A

### TSL Special Invited Speaker

Sponsored: Transportation Science & Logistics

Sponsored Session

Chair: Tom Van Woensel, Eindhoven University of Technology, Industrial Engineering, Den Dolech 2, Pav F08, Mb Eindhoven, NL5600, Netherlands

#### 1 - On Machine Learning and Discrete Optimization: Predicting Blurred Solutions for ILPs in Intermodal Container Loading

Andrea Lodi, cole Polytechnique de Montr al, GERAD-HEC, 3000 Chemin de la Cote-Sainte-Catherine, Montr al, QC, H3T2A7, Canada

In this talk, we advocate a tight integration of Machine Learning and Discrete Optimization (among others) to deal with the challenges of decision-making in Data Science. For such an integration, we briefly review possible directions and then we propose a methodology to predict descriptions of solutions to discrete stochastic optimization problems in very short computing time. We approximate the solutions based on supervised learning and the training dataset consists of a large number of deterministic problems that have been solved independently (and offline). Uncertainty regarding a subset of the inputs is addressed through sampling and aggregation methods. Our motivating application concerns booking decisions of intermodal containers on doublestack trains. Under perfect information, this is the so-called load planning problem and it can be formulated by means of integer linear programming. However, the formulation cannot be used for the application at hand because of the restricted computational budget and unknown container weights. The results show that standard deep learning algorithms allow to predict descriptions of solutions with high accuracy in very short time (milliseconds or less). A careful comparison with alternative stochastic programming approaches is provided. (Joint work with Eric Larsen, S bastien Lachapelle, Yoshua Bengio, Emma Frejinger, Simon Lacoste-Julien.)

## ■ TB32

North Bldg 222B

### Supply Chain Design and Operations I

Sponsored: TSL/Freight Transportation & Logistics

Sponsored Session

Chair: Burcu B. Keskin, University of Alabama, Tuscaloosa, AL, 35406, United States

#### 1 - Omni-channel Supply Chains with Unilateral Transshipments

Emily Barbee, University of Alabama, Tuscaloosa, AL, 35487-0226, United States, Burcu B. Keskin

Omni-channel supply chains integrate the brick-and-mortar and online sales channels of a company to achieve higher customer service and fill rates. Most

omni-channel supply chains facilitate unilateral transshipments to utilize in-store inventory to fulfill online demand. We quantify the impact of network design on inventory related costs and optimal order quantities. We maximize the profit of a newsvendor style problem and discuss concavity properties of the objective under different demand distributions.

#### 2 - Transportation Planning in the Beverage Container Recycling Industry

Robert Wiedmer, Arizona State University, Tempe, AZ, 85287, United States, Hakan Yildiz

In many U.S. states, empty beverage containers are returned to retail stores from where they are picked up and transported to processing facilities. Stochastic demand in the beverage industry challenges efficient routing of pick-up vehicles. We analyze data from a logistics service provider and present methods to optimize pick-up operations.

#### 3 - Strategic Network Design at the Polish Post

Maciek A. Nowak, Loyola University Chicago, Information Systems and Supply Chain Mgmt, Quinlan School of Business, Chicago, IL, 60611, United States, Mike Hewitt, Bogumil Kaminski, Michal Pliszka, Rahul C. Basole

Solving the Service Network Design (SND) problem assists a freight transportation firm by prescribing the choice of paths for shipments and the services or resources necessary to execute them, while achieving the economic and service-quality targets of the carrier. This research extends a previously developed SND algorithm while incorporating data visualization to assist the Polish Post in creating a more efficient and effective network.

#### 4 - The Strategic Value of Store Brands in a Common Retailer Channel

Hongseok Jang, University of Florida, Gainesville, FL, United States, Quan Zheng, Xiajun Amy Pan

In a common retailer channel with two asymmetric competing national brand manufacturers, we study whether the retailer should introduce a store brand. Our results reveal a continuum of boundary equilibria where the store brand with zero demand is offered so as to incentivize the manufacturers to lower the wholesale prices in a co-opetition manner.

## ■ TB33

North Bldg 222C

### Joint Session ORAM/QSR/Practice Curated: Panel Discussion on Academic Job Application and Interview Process

Emerging Topic: OR and Advanced Manufacturing

Emerging Topic Session

Chair: Mohammed Shafae, University of Arizona, Tucson, AZ, 85743, United States

#### 1 - Discussion on Academic Job Application and Interview Process

Ahmed Aziz Ezzat, Texas A&M University, College Station, TX, United States

Moderator for INFORMS annual meeting 2018 panel session entitled "Academic Job Application and Interview Process".

#### Panelists

Janis Terpenny, Penn State University, Industrial & Manufacturing Engineering, 310 Leonard Building, University Park, PA, 16802, United States

Elsayed A. Elsayed, Rutgers University, Department of Industrial and Systems Eng, 96 Frelinghuysen Road, Piscataway, NJ, 08854, United States

Zhijian Pei, Professor, Texas A&M University, 101 Bizzell St., College Station, TX, 77843, United States

Rachel Cummings, Georgia Tech, 755 Ferst Drive NW, Atlanta, GA, 30332-0205, United States

Murat Yildirim, Wayne State University, 4815 Fourth Street, Detroit, MI, 48202, United States

Mohammed Shafae, University of Arizona, Tucson, AZ, United States



## ■ TB34

North Bldg 223

**10:30 - 11:15 Frontline Systems, Inc/  
11:15 - 12:00 Artelys Corp.**

Vendor Demo Session

### 1 - Tutorial: Preview of Analytic Solver V2019 for Windows, Macintosh, and Office 365

Daniel H. Fylstra, Frontline Systems, Inc., P.O. Box 4288,  
Incline Village, NV, 89450-4288, United States

For many years, Frontline Systems has offered powerful data mining and machine learning, Monte Carlo simulation and risk analysis, and conventional and stochastic optimization in Analytic Solver<sup>®</sup> for Excel - on Windows. But use of Analytic Solver for Excel on Macintosh and the Web has involved challenges, due to differences within Excel. That's changing for the better in Analytic Solver V2019, which has been rewritten to work with new Excel internal APIs from Microsoft. Attend this session to see a preview of Analytic Solver V2019: uniformly powerful and easier to use than ever - on Excel for Windows, Macintosh, and Office 365.

### 2 - Introducing the New API and Conic Solver in Artelys Knitro 11.0

Richard Waltz, Artelys, 150 N. Michigan Avenue, Suite 800,  
Chicago, IL, 60601, United States

Artelys Knitro is the premier solver for nonlinear optimization problems. This software demonstration will highlight two key features in the new, major Knitro 11.0 release. First, we will demonstrate the new callable library API. This new API allows the user to build-up a model in pieces while providing special structures to Knitro. Second, we will introduce the new solver in Knitro 11.0 specially designed for models with cone constraints. Some benchmarking results will be provided.

## ■ TB35

North Bldg 224A

**Data-Enabled Discovery and Applications in  
Air Transportation**

Sponsored: Aviation Applications

Sponsored Session

Chair: Lishuai Li, City University of Hong Kong, Kowloon, Hong Kong

### 1 - A Supervised Machine Learning Approach for Solving the Aircraft Recovery Problem

Navid Rashedi, Dartmouth College, 30.5 W. Wheelock Street, 1,  
Hanover, NH, 03755, United States, Vikrant Vaze

Commercial solvers have been used for solving aircraft recovery problems. However, obtaining high quality solutions within the limited time frames of online applications is challenging. We develop a data-driven approach to solve a broad class of aircraft recovery problems. This method can be applied to identify a near-optimal solution by using previously good solutions generated by decision-support tools, human experts, or a combination thereof. The performance of our method was tested by applying it to a set of real-world networks for a moderately large US carrier. The results showed that the obtained solutions were, on average, within a 5% optimality gap and were calculated within a few seconds.

### 2 - Characterization of Air Traffic Management Operations Based on Large-scale Flight Tracking Data

Lishuai Li, City University of Hong Kong, Tat Chee Avenue, P6606,  
AC1, Kowloon, Hong Kong, Pan Ren

Air Traffic Management (ATM) strategies and procedures vary by region. Comparing ATM in different regions could help us understand what works better and how to improve. However, few studies have done so due to lack of data. With Automatic Dependent Surveillance - Broadcast (ADS-B) adopted by many countries, it is possible for the first time to track and analyze aircraft movement data at global scale. I will present case studies to characterize actual ATM operations, i.e. network structure and dynamics, flow patterns, etc., via a data-driven approach. The result will enable us to understand current operations better, identify deficiencies, and provide recommendations for future improvement.

## ■ TB36

North Bldg 224B

**Joint Session Drones/Practice Curated:  
New Directions in Logistics**

Emerging Topic: Robotics, Drones and Autonomous Vehicles in Logistics

Emerging Topic Session

Chair: Dongdong Ge, Shanghai University of Finance and Economics

### 1 - An Efficient MILP Formulation for Real AGV Systems

Dongdong Ge, Shanghai University of Finance and Economics,  
School of Information Management and Eng, 777 Guoding Road,  
Shanghai, 200433, China

Running more than 100 robots in an AGV system is the main difficulty in most AGV warehouses. This project approaches this real time control problem by efficiently formulating its assignment part as an MILP problem, solving it efficiently, and combining it with intelligent partition system and vehicle routing algorithms. The implementation results in Beijing's large warehouse in 2017 showed a great success for 'double eleven' shopping rush.

### 2 - Last Mile Delivery using Trucks, Drones, and Ground-based Robots

John Gunnar Carlsson, University of Southern California, 3750  
McClintock Avenue, Los Angeles, CA, 90089, United States

We determine the efficiency of a delivery system in which a truck acts as a "moving warehouse" for a collection of drones or ground-based robots. Using a theoretical analysis in the Euclidean plane, we derive a closed-form expression describing the time to completion in terms of the number of drones or robots as well as the relative speeds of the vehicles.

## ■ TB37

North Bldg 225A

**APS-Special Speaker**

Sponsored: Applied Probability

Sponsored Session

Chair: Harsha Honnappa, Purdue University, West Lafayette, IN, 47906, United States

Co-Chair: Henry Lam, Columbia University, New York, NY, 10027, United States

### 1 - Data-integrated Stochastics: Models And Methods

George Shanthikumar, Purdue University, West Lafayette, IN,  
47906

This tutorial will review the current data integrated approaches for predictive and prescriptive analysis of stochastic systems. In particular we will review: 1) approaches such as Multi-Armed Bandit, Regularization in Sample Average Approximation and Data Driven Robust Optimization for generating prescriptive solutions to stochastic systems, and 2) some of the Machine Learning approaches used for predictive analysis of stochastic systems. We will then provide a framework for data integrated methodology for predictive and prescriptive analytics for stochastic systems. Specific attention will be paid to overcoming structural and statistical errors.

## ■ TB38

North Bldg 225B

**Joint Session APS/Practice Curated:Data Driven OR  
Applications**

Sponsored: Applied Probability

Sponsored Session

Chair: Flora Spieksma, Leiden University, Leiden, 2311KL, Netherlands

Co-Chair: Michael N. Katehakis, Rutgers University, Newark, NJ,  
07010, United States

### 1 - Non-parametric Up-and-down Experimentation Revisited

Flora Spieksma, Associate Professor, Leiden University, Niels  
Bohrweg 1, Leiden, 233CA, Netherlands, Michael N. Katehakis,  
Sheldon M. Ross

In many applications, it is of interest to estimate a value, the 'quantile', of a scalar control variable  $x$  that will cause a certain ratio  $\alpha$  of successes, or failures, in a binary output variable  $Y = Y(x)$ . We present a convergent algorithm for estimating the quantile  $x^*$  and we discuss applications in inventory control under unknown demand distribution, and drug dosage determination.

## 2 - Asymptotically Optimal Multi-armed Bandit Policies Under Side Constraints

Odysseas Kanavetas, Koc University, Koc University Campus, Istanbul, Turkey, Apostolos Burnetas, Michael N. Katehakis

We develop asymptotically optimal policies for the multi armed bandit (MAB), problem, under side constraints. Such models are applicable in situations where each sample (or activation) from a population (bandit) incurs known bandit dependent costs. We consider the class of feasible uniformly fast (UF) convergent policies, that satisfy sample path wise the constraints. We first establish a necessary asymptotic lower bound for the rate of increase of the regret function of UF policies. Then we provide conditions under which a simple class of UF policies attain this lower bound and are asymptotically optimal within the class of UF policies.

## 3 - Generative Networks for Data Modeling in Sequential Change Detection

George Moustakides, Professor, Rutgers University, 110 Frelinghuysen Road, Hill 359, Piscataway, NJ, 08854, United States

One of the most important problems in applications is data modeling. When data are time-dependent, we limit ourselves to linear AR or ARMA models therefore silently assuming that the data are Gaussian. Recently, in Machine Learning, nonlinear neural network, known as Generative Networks, were introduced that can be properly trained to capture non-Gaussian behavior. In this work we extend this idea to represent nonlinear time-dependencies instead of simple independent realizations which is the current practice. Our method is then applied to the problem of sequential change detection for the rapid detection of changes in the statistical behavior of observed processes.

## 4 - Reinforcement Learning: Connections Between MDPS and MAB Problems

Michael N. Katehakis, Distinguished Professor, Rutgers University, 100 Rockefeller Road, Piscataway, NJ, 08854, United States, Wesley Cowan, Daniel Pirutinsky

This talk considers a basic reinforcement learning model dealing with adaptively controlling an unknown Markov Decision Process (MDP), in order to maximize the long-term expected average value. We show how a factored representation of the MDP problem allows it to be decoupled into a set of individual MAB-problems on a state by state basis. Additionally, i) we show the construction of a simple UCB-type MDP policy, dramatically simplifying an earlier proof of its optimality, and ii) we discuss extensions to other MAB policies e.g., Thompson Sampling.

## ■ TB39

North Bldg 226A

### Online Optimization and Probability

Sponsored: Applied Probability

Sponsored Session

Chair: Alessandro Arlotto, Duke University, Durham, NC, 27708, United States

## 1 - On Policies for Single-leg Revenue Management with Limited Demand Information

Will Ma, Google, Cambridge, MA, United States, David Simchi-Levi, Chung-Piaw Teo

In this paper we study the single-leg revenue management problem, with no information given about the demand trajectory over time. The competitive ratio for this problem has been previously established under the assumption of independent demand, i.e. demand from higher fare classes do not spill over to lower fare classes. We extend these results to general demand, by using a price-skimming technique. That is, we derive price-skimming policies which stochastically-increase their price distributions as inventory decreases, in a way that yields the best-possible competitive ratio. A key technical ingredient in our paper is a new "valuation tracking" subroutine.

## 2 - Adaptive Policies for the Dynamic and Stochastic Knapsack Problem with Equal Values

Xinchang Xie, Duke University, 100 Fuqua Drive, Durham, NC, 27708, United States, Alessandro Arlotto

We study a dynamic and stochastic knapsack problem in which a decision maker is sequentially presented with  $n$  items and needs to select which items to include in a knapsack with fixed capacity. Arriving items have non-negative, independent sizes with common continuous distribution, and every decision is terminal upon arrival. The goal is to maximize the expected number of selections under capacity constraint. Under mild regularity conditions on the distribution, we propose adaptive online policies that are within  $O(\log n)$  of optimal. Moreover, the limiting distribution of the number of selections under such policies is the same as the distribution that one obtains by implementing an optimal policy.

## 3 - Uniformly Bounded Regret in the Multi-secretary Problem

Alessandro Arlotto, Duke University, 100 Fuqua Drive, Durham, NC, 27708, United States, Itai Gurvich

In the secretary problem of Cayley (1875) and Moser (1956),  $n$  non-negative, independent, random variables with common distribution are sequentially presented to a decision maker who decides when to stop and collect the most recent realization. The goal is to maximize the expected value of the collected element. In the  $k$ -choice variant, the decision maker is allowed to make  $k=n$  selections to maximize the expected total value of the selected elements. Assuming that the values are drawn from a known distribution with finite support, we prove that the regret-the expected gap between the optimal online policy and its offline counterpart-is uniformly bounded in the the number of candidates  $n$  and the budget  $k$ .

## 4 - The Bayesian Prophet Framework for Low Regret Online Decision-making

Siddhartha Banerjee, Cornell University, 229 Rhodes Hall, Ithaca, NY, 14853, United States

We propose a new framework for online policies for packing problems with stochastic arrivals, based on access to an oracle that provides statistical information regarding the offline optimal solution. Our policy, which we call the Bayes Selector, is a simple greedy policy for general online decision-making problems based on such an oracle. We provide a general technique for deriving expected regret bounds for this policy, and prove that in any online packing problem with a discrete type space, the Bayes Selector achieves an expected regret which is independent of the number of arrivals and the starting resource levels.

## ■ TB40

North Bldg 226B

### Research and Funding Trends in Decision Analysis

Sponsored: Decision Analysis

Sponsored Session

Chair: Christian Wernz, Virginia Commonwealth University-VCU, P.O. Box 980203, Richmond, VA, 23298, United States

#### Moderator

Christian Wernz, Virginia Commonwealth University-VCU, P.O. Box 980203, Richmond, VA, 23298, United States

#### Panelists

Robin Dillon-Merrill, National Science Foundation, 517 Hariri Building, McDonough School of Business, Washington, DC, 20057, United States

Georgia-Ann Klutke, National Science Foundation, 4201 Wilson Boulevard, Arlington, VA, 22230, United States

Irina Dolinskaya, National Science Foundation, 2415 Eisenhower Ave, Alexandria, VA, 22314, United States

## ■ TB41

North Bldg 226C

### Environmental Decision Analysis

Sponsored: Decision Analysis

Sponsored Session

Chair: Melissa A. Kenney, University of Maryland, College Park, MD, 20740, United States

Co-Chair: Sayanti Mukherjee, Purdue University, West Lafayette, IN, United States

## 1 - A Comparison of Spatial and Random Failures when Simulating Network Outages

Benjamin Rachunok, Purdue University, 315 N. Grant Street, West Lafayette, IN, 47906, United States

In network-based analyses of infrastructure failures and recovery, small perturbations in initial outages can cascade through the system causing wildly differing end-stage outage patterns. Frequently in these analyses, random nodes are selected for removal to simulate the degradation of system due to tropical storms. In this case we evaluate this random node selection technique against outages which are spatially motivated by the actual outage patterns caused by tropical storms. The resulting outage and recovery patterns are analyzed for differences.

## 2 - Insights Revealed by the Value of Information in a Multiple-objective Decision: Brown Trout in the Grand Canyon

Michael C. Runge, USGS Patuxent Wildlife Research Center,  
12100 Beech Forest Rd, Laurel, MD, 20708, United States, Charles  
B. Yackulic, Lucas S. Bair, Theodore A. Kennedy, Richard A. Valdez

Brown trout (*Salmo trutta*) have expanded their range in the Colorado River ecosystem, possibly threatening a delicate balance among multiple objectives, including recovery of the endangered humpback chub (*Gila cypha*) and ecosystem restoration. We examined possible causal mechanisms for the expansion, and used an expected value of information analysis to evaluate potential management interventions. The EVPI analysis reveals there is important uncertainty impeding any response, with respect both to reducing the number of brown trout and to achieving other objectives. Some potential actions, however, are more robust to uncertainty than others, pointing toward initial interventions.

## 3 - Coastal Sustainability Management using Avulsion Mitigation Strategies in the Yellow River Delta under Climate Change

Liang Chen, Johns Hopkins University, Baltimore, MD, 21210, United States

Due to high in-channel sedimentation rates, China's Yellow River has changed course frequently, with huge socioeconomic impacts. We will address questions: What is the best timing and location of deliberate avulsions? Can use of temporary floodways lessen the cost and flooding impact, and if so where should they be located and how should they be operated? A simulation-based optimization model has been developed considering tradeoffs between cost of engineered construction and flooding risk. A robust adaptive decision model has been implemented to consider adaptive changes in operations as deep uncertainties in socioeconomic and climatic pressures evolve in the future.

## 4 - Value of Decision Analysis for Climate Adaptation Planning: Which Adaptation Decisions Can Benefit Most?

Rui Shi, Johns Hopkins University, Baltimore, MD, United States

Decision analysis, considering uncertainty and adaptability, can provide useful insights for climate adaptation planning. However, adaptation managers should conduct such analyses only when the expected improvement in performance justifies the expense of the analysis. We first develop a screening tool to assess if adaptation decisions could be significantly improved by a risk-based multistage decision analysis. We then propose a procedure which quantifies nine characteristics that are associated with problems that can benefit from decision analysis. We then use the framework to prioritize adaptation decisions in the Mid-Atlantic region that are candidates for applying decision analysis.

## ■ TB42

North Bldg 227A

### Joint Session Analytics/Practice Curated: Analytics and Machine Learning in Healthcare

Sponsored: Analytics

Sponsored Session

Chair: Aven Samareh

## 1 - Balanced Random Survival Forests for Mortality Prediction from Extremely Unbalanced, Right Censored Data

Kahkashan Afrin, Texas A&M University, College Station, TX, United States, Gurudev Illangovan, Sanjay S. Srivatsa, Satish Bukkapatnam

Accuracies of survival models are compromised due to the imbalance between the survival and mortality class sizes. Imbalanced datasets results in an underestimation (overestimation) of the hazard of the mortality (survival) classes. A balanced random survival forests (BRSF) model, based on training the RSF model with data generated from a synthetic minority sampling scheme is presented to address this gap. Benchmarking studies were conducted using five datasets from public repositories and a dataset of 267 patients, collected at the Heart, Artery, and Vein Center of Fresno. Investigations suggest that BRSF outperformed both Cox and RSF with an average reduction of 55% in the prediction error.

## 2 - Effects of Outliers and Robust Logistic Regression Tree

Doowon Choi, Texas A&M, College station, TX, United States, Li Zeng

This study investigates effects of outliers in logistic regression tree (LRT) modeling of binary outcome data in healthcare applications and develops a robust logistic regression tree (RLRT) approach that can alleviate those effects. The effectiveness and advantages of the proposed method is demonstrated in a case study using dataset on cardiac surgeries.

## 3 - A Semi-supervised AUC Optimization Model for Autism Risk Gene Prediction

Ying Lin, Houston, TX, United States

Autism is a constellation of neurodevelopmental presentations with high heritability. Prediction models, e.g. SVM and Random Forest, have been applied to automatically identified causal autism genes based on their expression patterns. But existing models are challenged by the limited training genes, imbalanced gene labels and the spatiotemporal correlations in gene expression. In this study, a semi-supervised AUC optimization model is developed to identified autism risk genes using brain specific gene expression value and their functional relationship network. It's applied to rank more than 25,000 unknown genes and the top ranked genes are potential to enrich the autism risk genes.

## 4 - Med-chi: Maximum Entropy Discrimination Based Contemporaneous Health Index for Degenerative Disease Monitoring

Aven Samareh, University of Washington, 4324 8th Ave NE, D7, Seattle, WA, 98105, United States, Shuai Huang

We developed a novel contemporaneous health index (MED-CHI) that builds on the theory of maximum entropy discrimination. MED-CHI aims to characterize the monotonic progression characteristic underlying the longitudinal measurements for degenerative disease monitoring. Intuitively, the MED-CHI approach embodies both the data integration power of Bayesian method and the computational power of convex optimization, to handle semi-supervised structure and transfer the learned knowledge to enhance the learning ability to a completely unsupervised source domain.

## 5 - Dynamic Inspection of Latent Variables in State-space Systems

Tianshu Feng, University of Washington, Seattle, WA, 98195, United States, Xiaoning Qian, Kaibo Liu, Shuai Huang

The state-space models are widely used in a variety of areas where a set of observable variables is used to track latent variables. While most existing works focus on the statistical inferences of the latent variables based entirely on the observable variables, it comes to our awareness that in many applications, the latent variables can be occasionally acquired to enhance the monitoring of the state-space system. In our work, novel dynamic inspection methods under a general framework of state-space models are developed to identify and inspect the latent variables that are most uncertain.

## ■ TB43

North Bldg 227B

### Planning and Operation of Storage Assets in Electric Networks

Emerging Topic: Energy and Climate

Emerging Topic Session

Chair: Mahdi Kefayati, Electric Power Engineers, Inc., Austin, TX, 78749, United States

Co-Chair: Duehee Lee, KonKuk University, Seoul, Korea, Republic of

## 1 - A Scalable Computational Method for Security-constrained Unit Commitment with Energy Storage

Edward Quarm, The University of Texas at Arlington, Arlington, TX, United States, Fariba Zohrizadeh, Ramtin Madani

We introduce a computational method for finding feasible and near-globally optimal solutions for detailed security constrained unit commitment (SCUC) problems in the presence of energy storage units, uncertainties, and reserve requirements. The proposed method relies on conic optimization for solving mixed-integer nonlinear programming problems with large number of binary variables. Experimental results on benchmark test cases demonstrate superiority of the proposed method over off-the-shelf solvers for unit commitment.

## 2 - Energy Storage Planning in Presence of Topology Control

Mostafa Sahraei-Ardakani, University of Utah, Salt Lake City, UT, 84112, United States, Yuanrui Sang

Energy storage has the potential to alleviate the intermittency of renewable generation. One important factor in energy storage planning is the congestion patterns, which will affect the size and location of such facilities. The congestion patterns, however, are affected by topology control. This talk discusses how frequent utilization of topology control will influence the optimal location and size of energy storage facilities.



### 3 - Optimal Energy and Regulation Market Bidding Strategies for ESS-integrated Wind Power Producers

Duehee Lee, Konkuk University, Kwangjin Gu, Seoul, Korea,  
Republic of, Seungwoo Son, Sini Han, Jae Hyung Roh

We present the optimal bidding strategy for wind power producers (WPPs) in the day-ahead (DA) energy and regulation markets. WPPs integrate the energy storage system (ESS) with wind farms to mitigate the imbalance penalty in the real-time (RT) market and to earn extra profits in the regulation market. Our bidding strategies in the DA market is designed and represented as offer curves by considering the optimal operation of the ESS for 24 hours and wind power and RT price forecasts. The ESS operation is determined by solving the multi-stage stochastic optimization problem through the progressive hedging algorithm. We show that our bidding strategy can have higher profits than a near-sighted strategy.

## ■ TB44

North Bldg 227C

### Distributed Optimization for Power Systems

Sponsored: Energy, Natural Res & the Environment/Electricity

Sponsored Session

Chair: Ross Baldick, University of Texas at Austin, Austin, TX, 78712, United States

Co-Chair: Subhonmesh Bose, University of Illinois-Urbana Champaign, Urbana, IL, 61801, United States

#### 1 - Market Mechanism Design for Horizontal and Vertical Coordination of Power System Expansion: Distributed Optimization Approach

Sambuddha Chakrabarti, 2000 Pearl Street, Room 113, Austin, TX, 78705, United States

In this work, we will consider long term generation & transmission expansion & investment coordination problems, where there are multiple Transmission System Planners (TSPs) & Generation Companies (GenCos). Each agent acts only to maximize its own utility. To attain the optimal social surplus for the bigger geographical region, we will use Distributed Stochastic Optimization algorithm to design a market mechanism. We will demonstrate our method with numerical simulations for the Nordic grid.

#### 2 - Transmission Expansion Planning via Distributionally Robust Optimization

Antonio J. Conejo, The Ohio State University, Department of Integrated Systems Engineering, 210 Baker Systems Building, Columbus, OH, 43210, United States

This presentation addresses the transmission expansion planning problem under long- and short-term uncertainty. Long-term uncertainty pertains to changes across years, whereas short-term uncertainty pertains to changes within a year. This problem is formulated as a distributionally robust optimization model, and is solved via a tailored implementation of the primal Benders' decomposition algorithm. The effectiveness of the proposed algorithm is illustrated through a realistic case study.

#### 3 - Convex Relaxations of the Network Flow Problem Under Cycle Constraints with Application to Electric Power Systems

Madi Zholbaryssov, University of Illinois at Urbana Champaign, Urbana, IL, 61801, United States, Alejandro Dominguez-Garcia

We consider a variation of the minimum-cost network flow problem (NFP) with additional non-convex cycle constraints on nodal variables; this problem has relevance in the context of optimizing power flows in electric power networks. We propose one approach to tackle the NFP that relies on solving a convex approximation of the problem, obtained by augmenting the cost function with an entropy-like term to relax the non-convex constraints. We show that the approximation error can be made small enough for practical use. An alternative approach is to solve the NFP without the cycle constraints and solve a separate optimization problem in order to recover the actual flows satisfying the cycle constraints.

#### 4 - Distributed Optimization for Solving Nonconvex Optimal Power Flow

Kaizhao Sun, Georgia Tech, Atlanta, GA, United States

Motivated by the problem of coordination between ISO markets, we study distributed optimization algorithms for the AC optimal power flow problem. We first give an overview of the field of distributed optimization with an emphasis on applications to OPF. Then we propose distributed algorithms for solving the convexified as well as the nonconvex versions of the AC OPF problems with provable convergence guarantees. Numerical results show promising performance.

### 5 - Robustness of Primal-dual Dynamics and its Implications for Online, Data-driven Optimization

Jorge Cortes, PhD, University of California-San Diego, La Jolla, CA, 92093, United States

Primal-dual strategies are used extensively in the design and analysis of distributed feedback controllers and optimization algorithms in many applications. In large-scale optimization, an aggregate objective along with the local computability of the constraints make the dynamics amenable to distributed implementation. Here, we discuss progress on establishing stability and robustness properties of primal-dual dynamics, paying special attention to input-to-state stability, and illustrate the implications for online optimization and data-driven implementations with performance guarantees.

### 6 - Prosumer-based Decentralized Power Supply

Sleiman Mhanna, University of Sydney, School of EIE, EIE Building J03, The University of Sydney, 2006, Australia, Gregor Verbic, Archie Chapman

Traditionally, most optimization models used in power systems are computed in a centralized fashion. However, the large increase in the penetration of distributed energy resources (DERs) on the low voltage side of the distribution network will put the centralized approaches under strain. The talk will focus on distributed algorithms for solving the problem of prosumer orchestration. The problem is computationally challenging as it explicitly considers the nonconvex AC power flow constraints and because the DER models require the use of mixed-integer variables to model them accurately.

## ■ TB45

North Bldg 228A

### Enhancing Power Grid Efficiency Through Mathematical Programming

Sponsored: Energy, Natural Res & the Environment/Electricity

Sponsored Session

Chair: Yu Zhang, Santa Cruz, CA, 4592921, United States

Co-Chair: Yihsu Chen, UC Santa Cruz

#### 1 - Mechanism Design for Demand Response in Electricity Markets

Sepehr Ramyar, University of California-Santa Cruz, Santa Cruz, CA, United States, Yihsu Chen

Contrary to the current practice of trading demand response in wholesale power markets, we investigate the application of mechanism design theory as a new framework for designing a demand response market. The proposed mechanism is truth-revealing and would eliminate information asymmetries in the current market design. It also eases computational burden of the ISO, and guarantees participation of prospective agents. We show how the properties of the proposed mechanism can complement the existing regulatory context and eliminate opportunities for manipulation by market participants.

#### 2 - Asynchronous Large-scale Decentralized Unit Commitment

Paritosh Ramanan, Georgia Institute of Technology, Atlanta, GA, 30324, United States

The unit commitment problem for power networks is a critical and a computationally challenging problem especially for large-scale power systems. We propose an asynchronous decentralized solution to the unit commitment problem that is computationally more efficient and is driven by privacy preserving valid inequalities. We benchmark our algorithm against a state of the art synchronous and the centralized method. In both cases, we demonstrate that our method is highly scalable, improves solution times and provides a competitive and stable solution quality.

#### 3 - Optimal Load Shedding via Mixed-integer Bilinear Programming

Yu Zhang, UC Santa Cruz, 1156 High St SOE2, Santa Cruz, CA, 95064, United States, Atif Maqsood, Keith Corzine

In this work we propose a novel design of optimal load shedding schedules for power distribution networks with multiple load zones. A mixed-integer bilinear optimization problem is formulated, which aims at minimizing the system-wise load shedding cost while achieving a desired reliability for industrial and residential users. Numerical results corroborate the effectiveness and merits of the proposed approach.

#### 4 - Efficiently Solving Linear Bilevel Programming Problems using Off-the-Shelf Optimization Software

Salvador Pineda, University of Malaga, Málaga, Spain,  
Henrik Bylling, Juan Miguel Morales

Many optimization models are formulated as bilevel problems. Most solution methods reformulate the bilevel problem as a mathematical program with complementarity conditions (MPCC). MPCCs are single-level non-convex optimization problems that do not satisfy the standard constraint qualifications and therefore, nonlinear solvers may fail to provide even local optimal solutions. In this paper we propose a method that first solves iteratively a set of regularized MPCCs using NL solvers to find a local optimal solution. Local optimal information is then used to reduce the computational burden of solving the Fortuny-Amat reformulation of the MPCC to global optimality using MIP solvers.

#### ■ TB46

North Bldg 228B

#### Enhance Energy Infrastructure Resilience with Operations Research

Sponsored: Energy, Natural Res & the Environment/Energy  
Sponsored Session

Chair: Feng Qiu, Argonne National Laboratory, Lemont, IL, 60439, United States

Co-Chair: Matteo Spada, Paul Scherrer Institut, Villigen PSI, 5232, Switzerland

#### 1 - A Bayesian Framework for Spatial Multi-criteria Risk Assessment: An Application to Oil Tankers

Matteo Spada, Paul Scherrer Institut, OHSA/D19, Villigen PSI, 5232, Switzerland, Valentina Ferretti

In recent years, increasing attention has been paid to the spatial nature of risk, mainly in the environmental decision-making domain since it commonly involves spatial impacts, spatial vulnerabilities and spatial risk-mitigation alternatives. In this context, spatial risk assessment procedures have been developed but they generally neglect the multi-dimensional nature of spatial impacts. In this study, we propose a Bayesian framework for spatial multi-criteria risk assessment to integrate uncertainty, model probabilities and multiple impacts. The presented model is applied and tested for tanker oil spills due to their international relevance and strong spatial dimension.

#### 2 - Resilient Power Distribution Grids from Planning to Restoration

Zhaoyu Wang, Harpole-Pentair Assistant Professor, Iowa State University, 1113 Coover Hall, Ames, IA, 50011, United States, Shanshan Ma, Anmar Arif

This talk will present our recent works on enhancing power distribution grid resilience. Specifically, we will firstly propose a two-stage stochastic model for long-term resilience-oriented design via infrastructure hardening and adding smart grid technologies. Then we will develop a co-optimization model for real-time coordination of crew repairs and remedial operations to accelerate the service restoration.

#### 3 - Recovery Logistics Co-optimization of Power Systems Against Natural Disasters

Yunhe Hou, University of Hong Kong, CYC Building, Room 508, Hong Kong, Hong Kong, Shunbo Lei

Efficient service restoration and infrastructure recovery after a natural disaster are one of the most critical requirements. First, repair crews should be optimally scheduled to recover the damaged components. Second, the system may need to be reconfigured for service restoration. Third, in some cases, mobile power sources are available to supply critical loads. There are also some other resources or strategies. We propose a framework, models, and algorithms to co-optimize major resources and strategies involved in power system recovery logistics. We show that such co-optimization based on our proposed method leads to more effective restoration of power systems.

#### 4 - A Heuristic Approach for Integrated Infrastructure Network Restoration Crew Routing Problem

Nazanin Morshedlou, University of Oklahoma, Norman, OK, 73071, United States, Kash Barker, Andres David Gonzalez

In this research, we consider the problem of restorative capacity enhancement problem in an infrastructure network which is interconnected with a routing network through which restoration crews are dispatched, from the originate depots, towards disrupted locations. Noting the complicated nature of resilience routing problems, we further propose a constructive heuristic algorithm which use a heuristic algorithm to improve the coordinated routes obtained from the relaxed form of the original formulations.

#### ■ TB47

North Bldg 229A

#### How to Influence and Improve Decisions Through Optimization Models

Emerging Topic Session

Chair: Jorge A. Sefair, Arizona State University, 699 S. Mill Ave., Tempe, AZ, 85287-8809, United States

#### 1 - How to Influence and Improve Decisions Through Optimization Models

Jeffrey D. Camm, Wake Forest University, School of Business, P.O. 7897, Winston-Salem, NC, 27109, United States

Industry's recent increased focus on data driven-decision making and the use of analytics in all sectors from sports to financial services to technology and healthcare has led to a resurgence in the interest in traditional operations research tools such as optimization, simulation, and decision analysis. As organizations mature analytically, it seems likely that we will see a further increase in interest in prescriptive analytics, including optimization modeling, which is the focus of this tutorial. With massive amounts of data being routinely collected in real time and an increased awareness on the part of management of the value of data, the availability of data is typically no longer the bottleneck in the optimization modeling process. Increased computing speed, improved algorithms, parallel processing, and cloud computing have increased the size of optimization problems that can be solved to optimality. Considering better data availability and the dramatic increase in our ability to solve problems, what are the impediments to keeping us from having significant influence and impact on decision making? Going forward, it is possible that our ability to (1) structure a messy decision problem into a useful optimization framework, (2) properly use the model to deliver valuable insights for management, and (3) communicate to management the value proposition of our insights, will become the new reasons we might fail to have the impact we know is possible. In this tutorial, we review types of optimization models and the art of modeling, that is, the process of going from mess to model. We discuss how to use an optimization model to provide not simply "the answer but insights that will be useful to managers and influence their decision making. We discuss the importance of communication in influencing, and provide examples and best practices relevant for optimization. We conclude with thoughts on how optimization modeling is important to the bustling fields of data science and artificial intelligence.

#### ■ TB48

North Bldg 229B

#### Supply Chain Information Disclosure Workshop II

Sponsored: Energy, Natural Res & the Environment Environment & Sustainability

Sponsored Session

Chair: Donna Marshall, University College-Dublin, Dublin, Ireland

Co-Chair: Steve New, University of Oxford, Oxford, OX1 3BW, United Kingdom

#### 1 - The Missing Link? The Strategic Role of Procurement in Building Sustainable Supply Networks

Veronica H. Villena, Penn State University, 412 Business Building, Supply Chain and Information Systems, State College, PA, 16802, United States

Some multinational companies (MNCs) require their (tier-one) suppliers to comply with their sustainability requirements and often to "cascade such requirements to their own (second-tier) suppliers. This research investigates why this cascading effect often fails and how procurement processes are deployed to engage tier-one and tier-two suppliers in MNCs' sustainability agendas.

#### 2 - Collective Disclosure in Complex Supply Chains

Jury Gualandris

Considering supply chains as complex networks of firms that get organized to achieve (and benefit from) interlocked behaviours, we theorize supply chain structures under which collective disclosure is more likely to occur. Collective disclosure happens when most firms in a supply chain publicly disclose large amounts of information to describe social and environmental practices and performance. Supply chain structures are analyzed in terms of diverse complexities such as numerosity, heterogeneity, interconnectedness and dynamism. We test our hypotheses using a novel data set of 226 supply chains that, overall, involve 5118 manufacturing firms and 20680 buyer-supplier contracts.

### 3 - How Blockchain can Disrupt the Supply Chain

Sara Saberi, Worcester Polytechnic Institute (WPI), Washburn  
Rm 217, Foisie School of Business, Worcester, MA, 01609,  
United States

Blockchain technology is increasingly being used in supply chain networks and logistics. With the absence of a central authority, blockchain technology provides a transparent, immutable, and authenticated platform that has a potential to provide traceability to manage sustainability practices and address economic, environmental, and social facets. However, as a disruptive technology, blockchain implementation would change supply chain cross-functional, cross-firm processes and require preparation. We explore various barriers, which stem from system limitations, different level of organizational activities through supply chain, and external authorities.

### 4 - The Cloud Supply Chain: Cyber-security Implications of the Hidden Chain

Steve New, University of Oxford, Oxford, United Kingdom,  
Olusola Akinrolabu, Andrew Martin

Cloud computing has revolutionised IT - but the revolution has complex implications for organizations wishing to understand their place in the electronic ecosystem. For many managers, cloud computing is a release from having to worry about the mundane details, allowing a focus on core competencies. But the cloud offerings are often opaque and sometimes deceptive: how exactly is the IT service being delivered? What services and systems are involved? Which companies are involved? This discussion will explore the fundamental questions of transparency, and describe initial efforts towards methods of mapping and risk assessment of the Cloud Supply Chain.

### 5 - Exemplars of Supply Chain Disclosure Innovations

Donna Marshall, University College Dublin, Carysfort Road,  
Dublin, Jakob Rehme, Lucy McCarthy, Paul McGrath

This study examines exemplar companies and the different methods they use to gather, analyse and publish supply chain sustainability disclosure in the public domain. Some of the world's most recognisable companies in the food, fashion, electronics, personal care, healthcare and homeware industries are presented in order to understand innovations in supply chain sustainability information disclosure and how these can be adapted for companies who are beginning their disclosure journey.

## ■ TB49

North Bldg 230

### Joint Session ENRE/Practice Curated: Open Pit and Underground Mining Applications

Joint Session

Chair: Alexandra M. Newman, Colorado School of Mines, Golden, CO,  
80401, United States

#### 1 - Managing Production Incidents in Mining using Multistage Stochastic Programming

Bernardo Kulnig Pagnoncelli, Universidad Adolfo Ibanez, Diagonal  
Las Torres 2640 Penalolen Of. 533-C, Santiago, 7910000, Chile,  
Lorenzo Reus, Margaret Armstrong

In this work, we consider a long-term mine planning model in the presence of price uncertainty and production incidents. The decision maker must satisfy minimum production levels established by contracts and can hedge against uncertainty by stocking material at a cost. We solve a large scale multistage stochastic programming model using decomposition methods and derive an optimal policy for any realization of the uncertain parameters.

#### 2 - Dispatching Policies in Open Pit Mining

Amanda G. Smith, University of Wisconsin-Madison, 1513  
University Avenue, Mechanical Engineering Bldg, Madison, WI,  
53706, United States, Jeff T. Linderth, James Luedtke

The open pit mine truck dispatching problem seeks to determine how trucks should be routed through a mine. Among the challenges of the dispatching problem is the need to balance the distinct objectives of meeting production and quality targets in a dynamic mining environment. We propose an optimization-driven approach to solving the dispatching problem via a MIP model. We also propose two competing policies that match dispatching decisions to rate targets obtained from a nonlinear flow rate model. To evaluate the policies, we use a discrete-event simulation of an open-pit mine. We conclude with computational results demonstrating how each policy performs on mines with different characteristics.

### 3 - Optimal Selection of Support Pillars in an Underground Mine

Levente Sipeki, Colorado School of Mines,, Golden, CO, 80128,  
United States, Alexandra M. Newman, Candace Arai Yano

We address the design optimization problem for a mine utilizing the top-down open-stope retreat mining method. Earth below the surface is divided into three-dimensional rectangular blocks. The mine design specifies which blocks are left behind as pillars to provide geotechnical structural stability; the remainder are extracted and processed. We maximize profit subject to geotechnical stability constraints and develop an iterative heuristic in which violated constraints are incorporated into the formulation until all required geotechnical constraints are satisfied. Our approach provides solutions whose estimated profit is 5% better than what industry-standard methods provide.

### 4 - Adaptive Scheduling under Uncertainty: Application to Open Pit Mining

Patricio Andres Lamas, Universidad Adolfo Ibanez, Santiago, Chile,  
Marcos Goycoolea, Bernardo Kulnig Pagnoncelli

In the mining industry, schedules are executed under high levels of uncertainty. Traditional scheduling approaches dealing with uncertainty consist of initially fixing an (execution-) policy class and then finding an optimal policy within such a class. These approaches have been successful in making the problem computationally tractable. However, initially fixing a policy class has a negative impact on the optimality of the schedules. We propose a less restrictive approach, which creates schedules that adapt to the uncertainty that is partially realized during execution. The adaptive capability of our approach leads to schedules that dominate those derived from the existing approaches.

## ■ TB50

North Bldg 231A

### Joint Session Practice/Practice Curated: O.R. Applications in Medicine

Sponsored: INFORMS Section on Practice (formerly CPMS)

Sponsored Session

Chair: Umit Deniz Tursun, University of Illinois, Champaign, IL, 61822,  
United States

#### 1 - Evaluation of Dexketoprofen Trometamol Ef?cacy in Postoperative Pain Management for Open Heart Surgery

Umit Deniz Tursun, University of Illinois, 3308 Sharp Drive,  
Champaign, IL, 61822, United States

To evaluate comparative statistical analgesic ef?cacy, opioid-sparing, and opioid-related adverse effects of intravenous dexketoprofen trometamol in combination with iv morphine postoperative open-heart surgery. Past data set and outcome predictions of different patient groups based on age and set of patient markers are presented. The opioid requirement is found to be lowered by %55 - 2.7 with %95 reliability. Routine addition of dexketoprofen trometamol to patient controlled analgesia morphine postoperative open-heart surgery is recommended as an alternative and ef?cacious method. The alternate postoperative pain therapy protocols are presented.

#### Panelists

Dr. Filiz Dokan, MD, Kosuyolu High Specialized Training and  
Research Hospital, Istanbul, 34865, Turkey

Umit Tursun Ozer, PhD, University of Illinois Urbana-Champaign,  
Champaign, IL, 61822, United States

Umit Deniz Tursun, University of Illinois, 3308 Sharp Drive,  
Champaign, IL, 61822, United States

## ■ TB51

North Bldg 231B

### Practice- Production & Scheduling I

Contributed Session

Chair: Carlos Monardes, Pontificia Universidad Catolica de Chile,  
Avenida Vi, Santiago, Chile,

#### 1 - Flexible Decisions and Flexible Resources: A Balance for Efficient Operations

Alejandro MacCawley, Catholic University of Chile, Santiago,  
Chile, Elbio Avanzini, Jorge R. Vera, Sergio Maturana

<Uncertainty in operational environments can be faced with operational flexibility in decisions as well as in resources. However, there are different costs involved, as well as the effects and operational consequences. In this work, we present a multi-stage stochastic optimization decision model, applied to a case in the agricultural industry. The model allows us to analyze the trade-offs between flexibility in the decision process as well as flexibility in the resources, like manpower skills. The analysis and conclusions help management to achieve a better operational planning under uncertainty.>



## 2 - A Column-generation Approach to Maximizing Angle Board Production

Samir Bhetwal, Northern Illinois University, Dekalb, IL, United States, Christine Vi Nguyen

The project focuses on providing a reliable solution to a paper production company producing angle boards. The company receives raw materials from the sister companies, and therefore has little control over the thickness of the paper that is used to create the angle boards. The column generation algorithm has been developed and a set of patterns are generated for each type of angle board product by which the production run can be maximized with the current available supply of raw materials. The model considers the current set of raw materials and its attributes in the production of good quality angle boards.

## 3 - Optimal Production and Inventory Planning with Inventory Based Financing

Renato E. de Matta, University of Iowa, 2360 Mulberry Street, Coralville, IA, 52241, United States, Vernon Hsu

We study a multi product, multi period production planning problem with restriction on the available working capital. We use cycle inventory as collateral to secure loans. We formulate the problem as a mixed integer programming model. The problem with one product is NP hard. We develop an efficient heuristic procedure to solve the multi product problem. We examine a variety of economic scenarios to show how the firm could significantly improve its profitability with the availability of inventory-based financing. We use real world data to validate our model and develop managerial insights.

## 4 - A Rhythm Wheel Approach for Production Planning and Batch Sizing

Gokhan Memisoglu, LLamasoft, Inc., 201 South Division St., Ann Arbor, MI, 48104, United States, Mike Bucci

In this study, we developed an optimization tool that includes line balancing, production cycle and sequencing. The intent of this tool is to create a high-level tactical solution which can guide a short-term production scheduling application. The tool uses Rhythm Wheel (RW) approach to estimate production cycles and creates a solution that balances setup and cycle stock costs. This tool has been used by a major pharmaceutical company in several project with great success.

## 5 - A Different Approach to Reduce Dimensionality in Planning Problems

Carlos Monardes, Pontificia Universidad Catolica de Chile, Avenida Vicuna Mackenna 4860, Macul, Santiago, Chile, Alejandro Francisco Mac Cawley, Jorge R. Vera, Susan C. Cholette, Sergio Maturana

Planning faces time dimensionality problems as instances size grows. In this work, we present a methodology to cope dimensionality. First, we defined a data structure to keep off time index in decision variables, which allowed us to construct a MIP model. Second, we solved the former problem using Constraint Generation. We tested this approach in winery industry, where model assists the assignment decision process of harvested grapes to fermentation tanks. This approach has shown interesting properties, increasing computational implementation efficiency.

## ■ TB52

North Bldg 231C

## Joint Session SMA/Practice Curated: Medical Decision Support with Social Media Analytics

Emerging Topic: Social Media Analytics

Emerging Topic Session

Chair: Qingpeng Zhang, City University of Hong Kong, Kowloon, 12180, Hong Kong

### 1 - Using Search Query Data to Predict HIV New Diagnoses

Qingpeng Zhang, City University of Hong Kong, 83 Tat Chee Avenue, 6/F, Academic 1, Kowloon, 12180, Hong Kong

Objectives: Internet data are important sources of abundant information regarding HIV epidemics and risk factors. A number of case studies found an association between Internet searches and outbreaks of infectious diseases, including HIV. In this research, we examined the feasibility of using search query data to predict the number of new HIV diagnoses in China. Design: We identified a set of search queries that are associated with new HIV diagnoses in China. We developed statistical models (negative binomial generalised linear model and its Bayesian variants) to estimate the number of new HIV diagnoses by using data of search queries (Baidu) and official statistics (for the entire country and for Guangdong province) for 7 years (2010 to 2016). Results: Search query data were positively associated with the number of new HIV diagnoses in China and in Guangdong province. Experiments demonstrated that incorporating search query data could improve the prediction performance in nowcasting and forecasting

tasks. Conclusions: Baidu data can be used to predict the number of new HIV diagnoses in China up to the province level. This study demonstrates the feasibility of using search query data to predict new HIV diagnoses. Results could potentially facilitate timely evidence-based decision making and complement conventional programmes for HIV prevention.

## 2 - Social Support and User Churn Prediction for Online Health Communities – A Trajectory-based Deep Learning Method

Xiangyu Wang, University of Iowa, Iowa City, IA, United States, Apoorva Joshi, Kang Zhao, Xun Wang

Online Health Communities (OHCs) are a great source of social support for patients and their caregivers. Better predictions of user churns from OHCs can help to manage and sustain a successful OHC. We incorporate two methods into churn prediction for OHCs: identifying different types of social support activities from posts users have published via text mining, and using LSTM to learn from users' trajectories in different types of social support activities.

## ■ TB53

North Bldg 232A

## Joint Session AMD/RMP: Incentives, Dynamics and Learning

Sponsored: Auction and Marketing Design

Sponsored Session

Chair: Vasilis Syrgkanis, Microsoft Research, Cambridge, MA, 02139, United States

### 1 - Dynamic Pricing/Auctions by Multi-scale Online Learning

Rad Niazadeh, Stanford University, 353 Serra Mall, Gate Bldg., Office 484, Stanford, CA, 94305, United States, Sebastien Bubeck, Nikhil Devanur, Zhiyi Huang

In this talk, I explore dynamic pricing/auctions from the perspective of online adversarial learning, inspired by the cloud pricing application. The model we consider is simple: a seller sells an identical item in each period to a new buyer (or a new set of buyers) by posting a different price at each time (or by running one of the possible incentive compatible auctions). The goal is to extract a revenue that (almost) matches the revenue of best posted price (or auction) in hindsight. For the online posted pricing problem, we show regret bounds that scale with the best fixed price, rather than the range of the values (with a generalization to learning auctions). Moreover, we demonstrate a connection between the optimal regret bounds for this problem and offline sample complexity lower-bounds of approximating optimal revenue, studied in [Cole and Roughgarden, 2015]. Using this connection, we show our regret bounds are almost optimal as they match these information theoretic lower-bounds. Our online auctions and pricing are obtained by generalizing the classical learning from experts and multi-armed bandit problems to their "multi-scale versions", where the reward of each action is in a different range. Here the objective is to design online learning algorithms whose regret with respect to a given action scales with its own range, rather than the maximum range. We show how a variant of online mirror descent solves this learning problem.

### 2 - Non-clairvoyant Dynamic Mechanism Design

Song Zuo, Tsinghua University, Beijing, China, Vahab Mirrokni, Renato Paes Leme, Pingzhong Tang

Despite their better revenue and welfare guarantees for repeated auctions, dynamic mechanisms have not been widely adopted in practice. This is partly due to their implementation complexity and unrealistic use of forecasts. We address the shortcomings and present a new family of dynamic mechanisms that are simple to compute and require no future distribution knowledge. We introduce the concept of non-clairvoyance in dynamic mechanism design, which means the allocation and pricing rule does not depend on future type distributions. We develop a framework to characterize the revenue extraction power of non-clairvoyant mechanisms against mechanisms with future distributional knowledge.

### 3 - Learning to Bid Without Knowing Your Value

Chara Podimata, Harvard University, 33 Oxford St, Cambridge, MA, 02138, United States, Zhe Feng, Vasilis Syrgkanis

We address online learning in complex auction settings, where the value of the bidder is unknown to her, evolving in an arbitrary manner and observed only if the bidder wins an allocation. We leverage the structure of the utility of the bidder and the partial feedback that they typically receive in auctions, in order to provide algorithms with regret rates that are exponentially faster in terms of dependence on the action space, than generic bandit algorithms. For that, we analyze a new online learning setting with outcome-based feedback, generalizing learning with feedback graphs. Lastly, we verify experimentally the performance of our algorithm and its robustness to noise in the feedback received.

#### 4 - How to Make Envy Vanish Over Time

Christos-Alexandros Psomas, Carnegie Mellon University, 5000 Forbes Avenue, GHC 9116, Pittsburgh, PA, 15213, United States, Gerdus Benade, Aleksandr Mark Kazachkov, Ariel Procaccia

We study the dynamic fair division of indivisible goods. Suppose  $T$  items arrive online and must be allocated upon arrival to one of  $n$  agents, each of whom has a value in  $[0,1]$  for the current item. Our goal is to design allocation algorithms that minimize the maximum envy at time  $T$ , defined as the maximum difference between any agent's overall value for items allocated to another agent and to herself. An algorithm has vanishing envy if the ratio of envy over time goes to zero as  $T$  goes to infinity. We design a polynomial-time, deterministic algorithm that achieves vanishing envy, and show that it is asymptotically optimal. We also derive tight bounds for a more general setting where items arrive in batches.

## ■ TB54

North Bldg 232B

### Issues in Behavioral Operations

Sponsored: Behavioral Operations Management

Sponsored Session

Chair: Elena Katok, University of Texas at Dallas, Richardson, TX, 75080, United States

#### 1 - The Behavioral Traps of Making Multiple, Simultaneous, Newsvendor Decisions

Shan Li, City University of New York, Baruch College, 55 Lexington Avenue, New York, NY, 10010, United States, Kay-Yut Chen

This paper conducted an experimental study to explore behaviors of newsvendors who make order decisions for two products simultaneously. We find that the decision performance is significantly reduced if a high-margin product is grouped with a low-margin product, but not so if it's grouped with another high-margin product. Our study has implication on how multiple products should be grouped and managed.

#### 2 - Using Strategic Buckets for Aligning Managers' Decisions with Companies' Objectives

Ulrich Thonemann, Professor, Universitat zu Koln, Business School, Albertus Magnus Platz, Koeln, D-50923, Germany, Andreas Fuegener

From a company's perspective, managers tend to over-invest in incremental projects and to under-invest in innovative ones. We analyze how strategic buckets can be used for aligning the investment decisions of individual managers with the company's objectives. Strategic buckets have been implemented in practice, but it is unclear how managers respond to them and how companies should design them. We present a behavioral model and report the results of laboratory experiments on the effect of strategic buckets on project selection.

#### 3 - The Role of Numeracy in Forecast Compliance, Trust and Usability

Elena Katok, University of Texas at Dallas, 800 W. Campbell Rd., Jindal School of Management (SM30), Richardson, TX, 75080, United States, Tobias Stangl, Gary E. Bolton

In procurement interactions, the relationship between the buyer and the seller starts after the sourcing decision has been made. In this study we consider ways to design a scorecard to best incentivize the suppliers.

## ■ TB55

North Bldg 232C

### Joint Session Sports/Practice Curated: Sports Analytics V

Sponsored: SpORts

Sponsored Session

Chair: Scott Nestler, University of Notre Dame, Granger, IN, 46530, United States

#### 1 - Analysis of Experimental Rule Changes in the 2018 National Invitation Tournament

Scott Nestler, University of Notre Dame, 51344 Pebble Beach Court, Granger, IN, 46530, United States

In recent years, the National Collegiate Athletic Association (NCAA) has used the National Invitation Tournament (NIT) as a test bed for rule changes under consideration. 2018 modifications included: (1) 3-point line extended by 20 inches; (2) lane expanded from 12 to 16 feet (NBA width); (3) 20-minute halves

split into two 10-minute quarters; and (4) resetting the shot clock to 20 (vs 30) seconds after an offensive rebound. In anticipation of the next possible rule change in 2019, this analysis quantifies the effect of these modifications on the college basketball game, through comparison with regular season and other post-season tournament games.

#### 2 - Age Effects in Mixed Martial Arts Competition

Thomas Robbins, East Carolina University, 3212 Bate Building, Greenville, NC, 27858, United States

The impact of age on sports performance has been analyzed in multiple sports including baseball, hockey, soccer, swimming, golf, track and field, and tennis. In this talk, we examine the impact age has on performance in mixed martial arts competition. We find that the age distribution varies significantly with weight class; as smaller more athletic weight classes are younger than the larger weight classes. We also quantify the impact age and age differential have on a fighter's probability of winning. Finally, we investigate whether the age distribution has been impacted by anti-doping policies and USADA testing.

#### 3 - MeetOpt: A Spreadsheet-based Decision Support System for Optimal Athlete-to-Event Assignment in Track and Field

Matthew Bailey, Bucknell University, School of Management, Taylor Hall, Lewisburg, PA, 17837, United States, Maciek A. Nowak

Nationally, track and field is second only to football in participation. Time-constrained track coaches primarily focus on the training and development of athletes. As a result, they overlook and underappreciate the competitive advantage of strategically assigning athletes to events. Working with local coaches, we developed a spreadsheet-based DSS, MeetOpt. MeetOpt is a generalization and extension of an assignment problem which determines an optimal athlete assignment to maximize the expected total team points. We illustrate the value of this model in comparison to commercially available tools and under a variety of scenarios, league rules, and preferences.

#### 4 - Team-specific Ticket Options

Ovunc Yilmaz, University of Notre Dame, South Bend, IN, 46617, United States, Mark Ferguson, Pelin Pekgun, Guangzhi Shang

Team-specific ticket options have recently gained popularity in the sports industry. In this study, we investigate the drivers of prices and transaction volumes in this market using social media data and detailed game/ranking information.

## ■ TB56

West Bldg 101A

### HAS Distinguished Scholar Lecture – Stefan Scholtes

Sponsored: Health Applications

Sponsored Session

Chair: Ebru Korular Bish, Virginia Tech, Blacksburg, VA, 24060, United States

Co-Chair: Tinglong Dai, Johns Hopkins University, Baltimore, MD, 21202, United States

#### 1 - The Healthcare Management Department of Management Science: How Can we Create and Support Impactful Research?

Stefan Scholtes, University of Cambridge, Judge Business School, Trumpington Street, Cambridge, CB2 1AG, United Kingdom

In contrast to other Management Science departments, the new healthcare management department focuses on a specific industry. This should be attractive to authors because their papers do not need to address a general context or contribute to general theory. However, the luxury comes at a price: Papers in the department have to provide insights that are of immediate interest and relevance for senior leaders in the industry. I will discuss this challenge, provide a few illustrative examples of attempts from my own work, and would then like to hear from the audience how we can achieve more practical impact with our research, while maintaining the high methodological standards of Management Science.

## ■ TB57

West Bldg 101B

### Health Applications

Sponsored: Health Applications

Sponsored Session

Chair: Osman Ozaltin, North Carolina State University, Raleigh, NC, 27605, United States

#### 1 - Operating Room Capacity Allocation Among Indoctors and Outdoctors Under Uncertainty

Tonguc Yavuz, Ozyegin Universitesi, Istanbul, Turkey, Serhat Gul, Erhun Kundakcioglu

The hospitals that have high-tech equipments or specialize in specific areas improve their revenues by allowing the doctors that are not employed by the hospital to use their own operating rooms. We study the problem of OR capacity allocation among indoctors and outdoctors over a planning period. The problem is formulated as a two-stage stochastic mixed integer program. We exploit the structural properties of our model to improve the computational performance of the standard stochastic programming techniques. We conduct numerical experiments based on data from a major hospital.

#### 2 - Data Analytics on the Operations of a Radiology Workflow Platform: Statistical Evidence of Cherry-picking and its Impact on Service Level

Gonzalo Romero, Rotman, University of Toronto, 91 Ferrier Avenue, Toronto, ON, M4K 3H6, Canada, Timothy Chan, Nicholas Howard, Saman Lagzi

Most hospitals follow an unstructured process for assigning cases to radiologists, providing ample freedom to select the next case to work on. We analyze a large and unique dataset from the operations of a radiology workflow platform. In particular, we explore whether the point system that Medicare uses to measure complexity -and ultimately for compensating hospitals and radiologist- is aligned with the amount of work required to process each case. We find that there exist some misalignment, which opens the door for radiologists to process cases that give a higher bang-per-buck first. We provide the first statistical evidence of cherry-picking in the processing of radiological cases.

#### 3 - Improving Patient Safety in the External Beam Radiation Therapy

Osman Ozaltin, North Carolina State University, Raleigh, NC, United States

The risk for errors is high in radiation therapy as the planning and delivery processes involve numerous hand-offs, each person interpreting and entering information via multiple complex electronic systems. The use of safety barriers (SB) is a widely recognized method for detecting errors before they harm patients. Each SB checks one or more treatment elements related to the outcomes of previous steps to ensure that they are accurate and meet safety standards. We develop an optimization framework to determine the reliable design of SBs to improve patient safety.

#### 4 - Emergency Department Pharmacy Staffing using Priority-based Workload

Phichet Wutthisirisart, Senior Health Services Analyst, Mayo Clinic, 200 First Street SW, Rochester, MN, 55905, United States, Maria Rudis, Kalyan Pasupathy, Mustafa Y. Sir

Pharmacists normally prepare prescription medication on demand and provide consultation on medication usage. Pharmacists based in Emergency Departments (EDs), unlike outpatient pharmacists, work closely with physicians to decide treatment plans for patients and assist physicians in resuscitation events. This work presents a novel approach implemented in Mayo Clinic's ED in Rochester to determine block schedules for staffing the ED pharmacy, based on patient volume with respect to task priority levels and estimated task response times. The comparison of pharmacy coverage before and after implementation showed that the ED achieved around 30 percent improvement.

## ■ TB58

West Bldg 101C

### Engineering Human Performance

Sponsored: Health Applications

Sponsored Session

Chair: Sheldon Herring, Greenville Health System, 701 Grove Rd, Greenville, SC, 29605, United States

Co-Chair: Dotan I. Shvorin, PhD, Clemson University, Freeman Hall, Clemson, SC, 29634, United States

#### 1 - Advancements in Athletic Performance Using Bio-Sensors and Simulation Modeling

Dotan I. Shvorin, Clemson University, Clemson, SC, United States

A proof of concept research was constructed to test if the integration of bio-sensing technology with advance analytical tools could provide advantageous insights to human performance. The study integrated a step-wise design with an action research approach. Each phase of the study, which included tennis drill design, simulation modeling, capturing the player baseline and game performance, model calibration, and optimization modeling, was tested, revised, and validated. By evaluating decision making outcomes, the proposed model presented a predicted player performance improvement capability of 18%, 11%, and 4% at the amateur, intermediate and advance skill level of play.

#### 2 - Effect of the Designed Environment on Individuals with Behavioral Disorders

Meirav Goldhour, Professor, Converse College, Spartanburg, SC, 29681, United States

Elements within our built environment such as color, light, view, materials, and space planning, can have an impact on mental and physical wellbeing. By way of example, research supports that certain colors can increase or decrease blood pressure, light can have an impact on concentrations, and space organization can improve human performance. Some design features can trigger negative memories, create discomfort, and be translated adversely by individuals with elevated sensitivities, such as Trauma and PTSD sufferers. With this knowledge in progress, design guidelines taken from related multidisciplinary fields have been formed towards promoting mental healing and performance.

#### 3 - Understanding Interruptions, Multitasking, and Workflow in the Emergency Department

Allan Fong, Medstar Health, 3007 Tilden Street, NW, Suite 7L, Washington, DC, 20008, United States

Understanding clinician workflow in healthcare settings is important to the safety and timely delivery of care. The emergency department specifically is one of the most interruption laden and chaotic environments where physicians have little to no control of the volume and acuity of their patients. Interruptions in healthcare environments are particularly risky given the potential for medical error and patient harm. We discuss a time-motion study observing 24 emergency physicians highlighting results and factors surrounding multitasking and interruptions.

#### 4 - Experience and Fatigue in Emergency Medicine Physician Decision Making

Kevin M. Taaffe, Clemson University, Department of Industrial Engineering, 269 Freeman Hall, Clemson, SC, 29634, United States, Dotan Shvorin

Emergency medicine physicians work in highly uncertain and intense care settings. After collecting data from a wearable bio-marker device, initial findings indicate that physician experience plays a role in developing internal control mechanisms to cope with various treatment conditions in the emergency room. Our research aims to detect not only the physiological differences between attending physicians and resident physicians, but also to detect when these physicians should change their workflow decisions to achieve better outcomes. Our findings will demonstrate how experience and physiological awareness of the physician can affect performance and result in better decision making.

#### 5 - Thinking with Your Brain in Mind: Learning More About the Learning Machine

Sheldon Herring, Greenville Health System, 701 Grove Rd, Greenville, SC, 29605, United States

The brain is the most complex system in existence and exists in a state of "dynamic stability". The brain continues to grow in complexity and mature, and is usually able to incorporate new information without destabilizing and losing its core identity. One of the most unique aspects of the brain is its self-awareness. Damage can result in changes in instability and result in "systems errors" that are counter-intuitive and range from changes in self-awareness to deficits in information processing. This session will provide an overview of the brain as a complex, dynamic and self-aware system and examples of how injury can result in impaired information processing and overview of neurorehabilitation.



## ■ TB59

West Bldg 102A

**Joint Session HAS/Practice Curated: Applications of Decision-Making Models in Healthcare**

Sponsored: Health Applications

Sponsored Session

Chair: Alireza Boloori, Arizona State University, Tempe, AZ, 85283, United States

**1 - Bias in Sensitivity Analysis of Comparative Analyses for Medical Decision Making**Michael J. Hintlian, University of Southern California,  
1029 South Westmoreland Avenue, #102, Los Angeles, CA, 90006,  
United States, Julia L. Higle

Comparative analyses for MDM are undertaken examine the cost/benefit impact of various treatment alternatives. These impacts are estimated via model-based analyses after which sensitivity to model parameters is examined. We illustrate the existence of bias in the sensitivity analysis that results from the methods used to select model parameters. We discuss methods for mitigating this bias.

**2 - Optimal Genetic Testing Schemes for Cystic Fibrosis**Hussein El Hajj, Virginia Tech, Blacksburg, VA, United States,  
Ebru Korular Bish, Douglas R. Bish

Cystic fibrosis (CF) is a highly prevalent life-threatening genetic disorder, but early diagnosis can save lives and reduce healthcare expenditures. To date, over 300 CF-causing mutations are identified, and all 50 states conduct newborn screening for CF, typically starting with a bio-marker test, followed by genetic testing on selected mutations for newborns with elevated bio-marker levels. We develop a stochastic optimization model to determine an optimal genetic testing scheme for CF that minimizes the probability of misclassification under a testing budget. Our case study for California shows that the optimal scheme can substantially reduce misclassification over current practices.

**3 - Incentive-Driven Readmission Management with Patients Facing Compliance Barriers**Aditya Mahadev Prakash, University of Florida, Gainesville, FL,  
32608, United States, Qiaochu He, Xiang Zhong

We aim to quantify the impact of non-compliance of patients on their post-acute care management, and assist healthcare stakeholders in improving the overall well-being of patients through the most efficient and effective allocation of resources. We establish a game-theoretic model where patients' lack of compliance is modeled by incorporating their heterogeneous and bounded rationality in the context of a congested service system. The optimal structure of subsidies that can monetarily incentivize patients and result in a minimum overall cost for an insurer is developed. The insights obtained from this study would support clinical and operational decision-making by health practitioners.

**4 - Impact of Physician's Ambiguity on Management of Medications**Alireza Boloori, Arizona State University, Tempe, AZ, 85283,  
United States, Soroush Saghaian, Harini A. Chakkerla,  
Curtiss B. Cook

Patients after organ transplantations receive high amounts of immunosuppressive drugs (e.g., tacrolimus) to reduce the risk of organ rejection. However, this practice has been shown to increase the risk of New-Onset Diabetes After Transplantation (NODAT). We propose an ambiguous POMDP framework to generate effective medication management strategies for tacrolimus and insulin. Our approach increases the patient's quality of life while reducing the effect of transition probability estimation errors. We also provide several managerial and medical implications for policy makers and physicians.

## ■ TB60

West Bldg 102B

**Scheduling in Healthcare Operations**

Sponsored: Health Applications

Sponsored Session

Chair: Jin Qi, Hong Kong University of Science and Technology  
Hong Kong**1 - A Predictive Analytics Framework for Personalizing Patient Encounters for Diabetes Care**Han Ye, U. of Illinois at Urbana-Champaign, 350 Wohlers Hall,  
1206 South Sixth Street, Champaign, IL, 61820, United States,  
Ujjal Kumar Mukherjee, Dilip Chhajed

In this paper, we develop a two stage decision framework that considers predicted diabetes risks of individual patients as inputs, which healthcare organizations can implement for optimally scheduling patient encounters for management of diabetes care.

**2 - Dynamic Appointment Scheduling of Elective Surgeries Under Bed Capacity Constraint**Chengyu Wu, Duke University, Durham, NC, 27705,  
United States, Li Chen, Jing-Sheng Jeannette Song

Both elective surgery patients and emergency surgery patients, after leaving operating room, need to enter the ICU that has a limited bed capacity. We study the problem of optimally scheduling elective surgeries in advance by taking into account the ICU capacity and occupancy. In doing so, we derive structural results and develop a heuristic which is validated using real-world hospital data.

**3 - Appointment Scheduling with a Waiting Time Target**Xing Liu, City University of Hong Kong, CITYU, Hong Kong,  
Frank Y. Chen, Jin Qi, Han Zhu

This work is motivated by the appointment booking of a care center, which accepts only advanced booking and patients should receive consultations within a stipulated target waiting time. We propose a heuristic for this advance booking problem through the policies of an allocation scheduling counterpart of the problem.

**4 - Operating Theater Scheduling Under Uncertainty with an Entropic Index**Xiaojin Fu, Hong Kong University of Science and Technology,  
Hong Kong, Jin Qi, Han Ye

We consider a surgery scheduling problem in an operating theater with uncertain surgery durations. We introduce the Entropic Tardiness Index (ETI) to quantify both the frequency and intensity of surgery delay or OR overtime. A mathematical model is formulated to find a sequencing decision which minimizes the ETI criterion, and an algorithm based on benders decomposition is developed to find the optimal solution. Inspired by a heuristic, we propose an index Entropic Deviation (ED) to account for both variation and skewness of surgery durations. Numerical study shows that sequencing decision obtained by sorting the EDs of the surgeries in the ascending order achieves a relatively good performance.

## ■ TB61

West Bldg 102C

**Optimization Society Award Session I**

Sponsored: Optimization

Sponsored Session

Chair: David Morton, Northwestern University, IEMS Department,  
2145 Sheridan Road, Evanston, IL, 60208, United States**1 - A Brief Tour of Logic and Optimization**John Hooker, Carnegie Mellon University, Tepper School of  
Business, Pittsburgh, PA, 15213, United States

This talk conducts a brief tour of the remarkable connections between logic and optimization, some of which have led to substantial improvements in solution technology. They include the fundamental role of logic in optimization duality and how it leads to logic-based Benders decomposition; the deep relationship between cutting planes and logical inference methods; linear and integer programming models for probabilistic, nonmonotonic, and belief logics; the role of logic's famous Herbrand Theorem in infinite-dimensional integer programming; binary decision diagrams as a discrete optimization tool; and how concepts of consistency in constraint programming relate to cutting plane theory.

**2 - A Simple Nearly-Optimal Restart Scheme for First-Order Methods**

James Renegar, Cornell University, Ithaca, NY, United States

I was lucky as a researcher to be coming of age when the "interior-point method revolution" was beginning to unfold, lucky to be in position to make a research contribution that was quickly and widely appreciated, a contribution that has played a significant role in now being honored with the Khachiyan Prize. The talk, however, focuses on recent research, presenting a simple restart scheme for first-order methods, which for rich classes of convex optimization problems results in algorithms with complexity bounds nearly matching lower bounds established by Nemirovski and Nesterov in the 1980's.

**3 - Stochastic Programming: Approximations and Scenarios**

Werner Roemisch, Humboldt Universitat, Berlin, Germany

Solving a stochastic program requires approximating a probability distribution with a finite set of scenarios. First, we review scenario generation using stability and probability metrics. Second, we describe a stability- and problem-based method to generate scenarios. For two-stage SPs this requires solving a generalized semi-infinite program, which reduces to a standard convex semi-infinite program in special cases. Third, we review quadrature using Monte Carlo, Quasi-Monte Carlo and sparse grid, and the method of moments, including convergence properties. We discuss numerical results.

**4 - Optimization Society's Khachiyan Prize**

David Morton, Northwestern University, IEMS Department,  
2145 Sheridan Road, Evanston, IL, 60208, United States

Winners of the Optimization Society's Khachiyan Prize will present their work.

**■ TB62**

West Bldg 103A

**Joint Session DM/Practice Curated: Modeling and Analysis of Complex Systems with Applications**

Sponsored: Data Mining

Sponsored Session

Chair: Chun-An (Joe) Chou, Northeastern University

Co-Chair: Miaolin Fan, Boston, MA, 02115, United States

**1 - A Novel Framework for Multimodal Physiological Data Fusion: Network Models of Nonlinear Dynamic Coupling Systems**

Miaolin Fan, Northeastern University, 360 Huntington Avenue,  
Boston, MA, 02115, United States

The human body is considered as a complex dynamic system of multiple physiological subsystems. A novel framework was proposed to present the system as a directed network, and the interrelationship among subsystems was quantified by fusing multimodal physiological time series. Each time series is projected onto a reconstructed state space, where the temporal dependency among system's states is captured. Then, a directed network model is formulated to characterize the coupling relationship between physiological subsystems with a temporally variable structure. We also discuss how the directed coupling can be assessed in the context of specific tasks, e.g. interpersonal communication.

**2 - Cost-sensitive Feature Selection using Mixed Integer Programming**

Daehan Won, Binghamton University, R4, Eng. Bldg, L2, Vestal,  
NY, 13902, United States, Shun Cao

Feature selection aims to select a subset of highly informative features that are capable of discriminating observations. Herein we consider the cost components in the selection since the traditional way may result in good selection in theory but not in practical applications. We are developing cost-sensitive classifier that minimizes the error caused by misclassification as well as maintaining the maximum amount of the cost to select the important features. To impose the cost directly, we construct two Mixed Integer Programming (MIP) models. To demonstrate the effectiveness, empirical experiments are conducted while showing that ours are capable of selecting a low-cost subset of features.

**3 - A General Embedding Framework for Heterogeneous Information Learning in Large-scale Networks**

Na Zou, Texas A&M University, 101 Bizzell Street, 4018 Emerging  
Technology Building, College Station, TX, 77845, United States

Network analysis has been widely applied in many real-world tasks. To extract features for these tasks, network embedding automatically learns a low-dimensional vector representation. However, it remains challenging to jointly embed the geometrical structure with heterogeneous information as well as problem of scalability. To bridge the gap, we propose a Heterogeneous Information Learning in Large-scale networks (HILL) to accelerate the joint learning. It decomposes the complex modeling into many simple and independent sub-problems. We illustrate the generalizability of HILL by applying it to perform attributed network embedding and second-order proximity learning.

**4 - A Low Rank Model for Estimation of Response Function in fMRI Data**

Minh Pham, Rochester Institute of Technology, Rochester, NY,  
22911, United States

The focus of this paper is on evaluating brain responses to different stimuli and identifying brain regions with different responses using multi-subject, stimulus-evoked functional magnetic resonance imaging (fMRI) data. To jointly model many brain voxels' responses to designed stimuli, we present a new low-rank multivariate general linear model (LRMGLM) for stimulus-evoked fMRI data. The new model not only is flexible to characterize variation in hemodynamic response functions (HRFs) across different regions and stimulus types, but also enables information "borrowing across voxels and uses much fewer parameters than typical nonparametric models for HRFs.

**■ TB63**

West Bldg 103B

**Joint Session DM/Practice Curated: Predictive Analytics and its Applications**

Sponsored: Data Mining

Sponsored Session

Chair: Talayeh Razzaghi

**1 - Using Predictive Analytics to Forecast Litigation Outcomes**

Mohammad Javad Feizollahi, Georgia State University, 755 First  
Drive NW, Atlanta, GA, 30332, United States, Charlotte Alexander

Text mining and predictive analytics are increasingly being used to analyze and forecast the outcome of lawsuits. In this project, we parse the text of thousands of court documents filed in federal employment law cases to discover features of the plaintiffs, defendants, lawyers, and judges, and the legal claims made in each case. Together, these features help construct a model that can be deployed at different phases of litigation to predict a case's outcome. We describe the methodology and results of this litigation prediction project.

**2 - A Sensor-driven Anomaly Detection Model with a Bayesian Hierarchical Framework**

Ramin Moghaddass, University of Miami, McArthur Engineering  
Building, Coral Gables, FL, 33146, United States

In this work, a new Bayesian hierarchical framework is presented that can be used to (a) model systems' response variables in terms of system's inputs (features) without imposing strong distributional assumptions, and (b) detect anomalies regardless of whether or not such anomalies have been observed before based on a trade-off between performance measures, such as true detection rate and false alarms. Using a Bayesian hierarchical setting, the model utilizes only a subset of important features and training samples in the training process.

**3 - A Two Objective Linear Programming Approach for Data Classification**

Elaheh Jafarigol, University of Oklahoma, Norman, OK, 73071,  
United States, Theodore B. Trafalis

Multi-objective optimization techniques are a useful tool for designing and analyzing supervised learning systems. This paper presents an optimization model to find support vector hyperplanes to classify large datasets with non-separable classes with modifications to the objective function in traditional support vector machine. To solve this optimization problem, parametric simplex for two-objective LPs is used. The model is implemented in Gurobi through Python to optimize the two-objective model.

**4 - Predictive Analytics in Humanitarian Supply Chain using Deep Learning**

Donovan Fuqua, New Mexico State University, 4208 Escondido  
Lane, Las Cruces, NM, 88005, United States, Talayeh Razzaghi

In this work, we propose the use of deep neural networks to predict shipment arrivals and system bottlenecks using multi-channel time series data. We use US Military transportation data from 2004-2015 for humanitarian relief supply chains. Although the research focuses on humanitarian operations, we will discuss multiple applications for supply chains and transportation optimization.

**■ TB64**

West Bldg 104A

**Joint Session DM/Practice Curated: Data Science for Block Chain, E-Business, and Commerce**

Sponsored: Data Mining

Sponsored Session

Chair: Lin Chen, University of Houston, 4800 Calhoun Road,  
Houston, TX, 77004, United States

**1 - Effect of Mimicking News Title on Sponsored Article Engagement**

Quan Wang, LinkedIn, 880 W. Maude Ave, Sunnyvale, CA, 94085,  
United States

Media companies are incorporating sponsored articles in the news feeds which used to be dedicated to editorial news articles. Using a large-scale novel dataset from a leading news website, we investigate whether mimicking news style affects the user engagement with the sponsored article. We employ a combination of human evaluation, natural language processing, binary classification models and econometrics models. We find evidence that mimicking the style of news title could lift the click probabilities by over 100% and increase conversion probability by 40%. Sub-analyses indicate that contextual congruity might be the driving force of the engagement lift.

## 2 - Using Omnichannel Sales Data Analytics to Decide Between Store and Distribution Center Fulfillment Options

Jingran Zhang, New Jersey Institute of Technology, University Height, Newark, NJ, 07102, United States, Jingran Zhang, Marshall University, Lewis College of Business, One John Marshall Drive, Corbly Hall 423, Huntington, WV, 25755, United States, Sanchoy Das

A brick-and-mortar retailer can fulfill online customer orders in two ways (i) Buy Online Fulfill from Store (BOFS) - Picked from store inventory, and (ii) Fulfill from Distribution Center (FDC) - Picked from DC or warehouse inventory. The fulfillment decision is made in real time for each order, with the primary goal of maximizing the revenue value of the store inventory. Analysis of sales data in both online and store channels is used to forecast the value of the dispersed inventory, and then develop a prescriptive model for making a fulfillment decision.

## 3 - Google Tells What Happens When Shadow Economy Meets Bitcoin

Zhesi Chen, First and Responding, Harbin Institute of Technology, Management Building 612, West Dazhi Street, Harbin, Heilongjiang China, Harbin, 150001, China, Wenjun Sun, Qiang Ye

In this study, we find striking positive correlations between Bitcoin's key financial indicators and the level of shadow economy, based on the geographic distribution of interests on Google Trend keyword "Bitcoin", along with the corresponding Shadow Economy Index data. Our results indicate that the shadow economy may be one of the key implicit factors driving Bitcoin's prosperity. Our study also shows that Google Trend can be an effective detector of economic and social drivers of Bitcoin.

## 4 - Identifying Companies with Prospects of Adopting Blockchain

Hamidreza Ahady Dolatsara, Auburn University, 227 Lowder Hall, 405 W. Glenn Ave., Auburn, AL, 36830, United States, Ashish Gupta, Alireza Farnoush, Gelareh Ahadi Dolatsara

This research identifies companies that may adopt blockchain technology based on their similarities to the companies that have already demonstrated an intention to use this technology. Long term financial performance of companies that intended to use blockchain technology is investigated for understanding the characteristics of such companies. Semi-supervised classification method is subsequently employed to identify similar companies.

## 5 - Smart Contract Execution – The (+)-Biased Ballot Problem

Lin Chen, University of Houston, 4800 Calhoun Road, Houston, TX, 77004, United States, Lei Xu, Zhimin Gao, Nolan Shah, Yang Lu, Weidong Shi

Transaction system build on top of blockchain, especially smart contract, is becoming an important part of world economy. We consider a blockchain-based smart contract system and study how the behavior of users would affect the consensus. We connect this problem to the classical Ballot problem in combinatorics and establish a more general (+)-Biased Ballot Problem to model it. We give an asymptotic analysis of this new model.

## ■ TB65

West Bldg 104B

### Data Science and Deep Learning I

Sponsored: Data Mining

Sponsored Session

Chair: Mohammadreza Soltani, Iowa State University, 3201 Coover Hall, Ames, IA, 50011, United States

## 1 - The Role of Community-based Norms in Carbon Emissions: A Machine Learning Exploration

Zhasmina Tacheva, SUNY at Buffalo, Buffalo, NY, 14210, United States, Anton Ivanov

Through the use of advanced machine learning and text mining techniques, this study analyzes a massive body of unstructured Twitter data in order to uncover patterns of common needs and values across all 3,007 counties in the U.S. The detected personality characteristics are then used to predict household carbon emissions at the county level. Concrete policy implications and important insights about ways to reduce carbon emissions through modifying consumer behavior at the local level are made.

## 2 - Embedding Machine Learning Into SAP Hana Applications

Sricharan Poundarikapuram, SAP America, 2996 N. 83rd Place, Scottsdale, AZ, 85251, United States, Doug Freud

The next wave of computing builds upon the Tabulation era that started in the 1900's and the Programmatic Computing era that started in the 1950's. The new class of analytic solutions leverage data combined with ML and other technologies to transform and automate tasks typically performed by humans. The SAP point of view is that next generation applications need to evolve from simple rules based programs into solutions that are powered by ML. Instead of hard coding

rules into applications, next generation solutions will be a combination of rules and probabilities dynamically generated via ML. In this session we will cover an overview of ML powered application that we built in SAP HANA and Cloud Platform.

## 3 - Data Driven Portfolio Optimization Utilizing Machine Learning

Meng-Chen Hsieh, Rider University, 2083 Lawrenceville Rd, Lawrence Township, NJ, 08648, United States

In practice, data-driven optimal portfolio decisions are derived using the time series data of underlying asset returns. Such data-driven optimal portfolio tends to have inferior out-of-sample performance due to estimation errors of parameters. In the 'big data' era, correlations between asset returns and auxiliary variables are frequently observed. In this talk, several machine learning methods are applied to derive the optimal portfolio leveraging the association between the underlying asset returns and auxiliary variables. A comparison study on the out-of-sample performance of the optimal portfolio with and without utilizing machine learning methods is conducted.

## 4 - A DQN Method for Progressive Generation of Solutions of VRPTW

Xiaodong Zhang, Artificial Intelligence Department, Zhejiang Cainiao Supply Chain Management Co., Ltd, Hang Zhou, China

We present a 'like-heuristic' framework for solving Vehicle Routing Problem with Time Window using Deep Q-learning Network. In this approach, instead of defining a specific heuristic policy to search the huge solution space, we make decisions according to the probability distribution of all customers to make progressive generation, by observing the reward signals and following feasibility rules.

## 5 - Fast and Provable Algorithms for Learning Two-layer Polynomial Neural Networks

Mohammadreza Soltani, Iowa State University, 3201 Coover Hall, Ames, IA, 50011, United States, Chinmay Hegde

We study the problem of (provably) learning of a two-layer neural network with quadratic activations. We focus on the under-parametrized regime where the number of neurons in the hidden layer is smaller than the dimension of the input. Our main approach is to "lift the learning problem into a higher dimension, which enables us to borrow techniques from low-rank matrix estimation. Using this intuition, we propose three novel, non-convex algorithms. We support our algorithms with rigorous theoretical analysis, and show that all three enjoy a linear convergence, fast running time per iteration, and near-optimal sample complexity. We complement our theoretical results with some experiments.

## ■ TB66

West Bldg 105A

### Joint Session AI/Practice Curated: Social Media and Surveillance: Detection and Prediction

Sponsored: Artificial Intelligence

Sponsored Session

Chair: Yongcheng Zhan, The University of Arizona, Tucson, AZ

## 1 - Learning User Age via Locality and its Applications in Regulatory Science: A Deep Learning-Based Approach

Zhipeng Chen, The University of Arizona, Tucson, AZ, United States, Daniel Dajun Zeng

The development of regulatory science requires researchers to utilize multiple data sources for assessing the safety, efficacy, quality and performance of all regulated products. The large quantity of social media data provides an opportunity to characterize public attitudes in real time. However, the lack of demographic data induces data biases and diminishes the utility of social media data. Our research mitigates this weakness by building a deep learning model to predict user age. The experiment shows the locality is a strong predictor and achieve a satisfiable prediction accuracy. Then we apply the prediction model to an e-cigarette dataset in an e-cigarette brand analysis. The analysis results indicate strong public health implications of demographics prediction.

## 2 - Illicit and Prescription Drug Street Name Detection using Social Media

Yongcheng Zhan, The University of Arizona, Tucson, AZ, 85719, United States, Zhu Zhang, Scott J. Leischow, Daniel Dajun Zeng

Recent years have observed the spread of America's drug overdose epidemic. Much effort has been made in public health surveillance to realize the potential of early detection and targeted intervention. However, because of the ever-changing drug street names, it is increasingly difficult for researchers and public health practitioners to keep up with the terms. We proposed an innovative method to automatically detect illicit and prescription drug street names by using rich text information from social media. Our method showed its potential by enriching NIH opioid street name list with emerging terms.



**3 - Detection of Prejudice from Social Media Streams**

Haimonti Dutta, University at Buffalo, 325P Jacobs Management Center, Buffalo, NY, 14260, United States

Multicultural societies are characterized by frequent contact and communication between different social groups. Prejudices, or beliefs about a particular social group, affect the nature and quality of interactions with members of that group. It finds expression in social media platforms when a group of people express anger, resentment and dissent towards another. It is heightened during crises or threat. This paper develops a framework for detection of prejudice from social media streams using deep learning methods. Empirical results presented on a Twitter data stream show that our framework is capable of out-performing state-of-the-art batch systems for prejudice detection.

**4 - Forecasting Collective Action using Social Media**

Rostyslav Korolov, Rensselaer Polytechnic Institute, 110 Eighth Street, Troy, NY, 12180, United States, David Mendonca, William A. Wallace

We demonstrate the potential of online social media for large-scale behavioral research by developing a multi-disciplinary approach to predicting collective action using social media data. We report three case studies: one concerning charitable donations and two concerning social unrest. Through these case studies we demonstrate the utility of social media data for predictions of different kinds of collective action. We utilize Twitter data (approximately 20 million messages) to predict the volume of disaster response donations, and occurrences of protests.

**5 - Predicting Gasoline Shortage in Florida During Irma using Tweets**

Abhinav Khare, University at Buffalo, Buffalo, New York, NY, United States, Rajan Batta, Qing He

Shortage of supplies during a disaster is a common issue. Social media usage during disasters also surges. We developed a model to infer demand of supplies during disaster using Twitter and tested it to infer gasoline demand that occurred in Florida during Irma. We built a support vector machine model combined with n-grams and topic models to classify tweets regarding demand and modelled the arrival of tweets as a Space-Time Poisson Process to infer the spatiotemporal demand. The model was tested on a database of 1.4 million tweets around Hurricane Irma in Florida. Our classification accuracy is high with f-score of 0.879 and the predicted demand correlates highly with the ground truth.

**■ TB67**

West Bldg 105B

**Platforms and Consumer Behavior**

Sponsored: Information Systems

Sponsored Session

Chair: Yuheng Hu, University of Illinois-Chicago, Chicago, IL, 60607, United States

**1 - Can (s)he Code? Gender Bias in an Open Source Software Community**

Tingting Nian, University of California, Irvine, UCI, Irvine, CA, United States

It is well-documented that women are underrepresented across all STEM fields and particularly in computing. Previous research identifies the negative stereotype about women's abilities is one of the leading reason. In order to scientifically examine the issue of gender bias in online open source software communities, our study investigates whether and to what extent there exists a gender bias in the programming question-and-answer site, Stack Overflow. Our results reveal a net discrimination of 0.4 votes per month against female participants, statistically significant at the one percent level. We also found evidence suggestive of the statistical discrimination at work.

**2 - Impact of Free Shipping Threshold on Different Channels: Evidence from an Online Retailer**

Fujie Jin, Kelley School of Business, Indiana University, 1309 E. Tenth Street, HH 4100, Bloomington, IN, 47401, United States, Fei Gao, Jianbin Li

In this working project, we use a unique data from an online retailer to look at customer padding behavior, with respect to a shipping fee change. Our preliminary evidence suggest that customers using the PC channel are more likely to pad their shopping cart to meet the minimum shipping fee, compared with customers using the mobile channel. We suggest that difference in search cost across the two channels is a main contribute to such different user behavior.

**3 - Visualizing Cybersecurity Risk Factors**

Arion Cheong, Rutgers University, Newark, NJ, United States, Won Gyun No, Soohyun Cho

The destructive nature of cyber threats makes it crucial for stakeholders of a firm to understand the cybersecurity risks that the firm faces. To outline a firm's known cybersecurity risks and identify its specific risks as compared to its industry peers, we utilize text mining to extract and analyze risk factor disclosures that firms report on Form 10-K. Since a comparison of cybersecurity risks through textual analysis is statistically infeasible, our approach visualizes each firm's

cybersecurity risks as an image in the comparison process. This visualization enables stakeholders' decision-making processes to easily access and compare cybersecurity risks.

**4 - Fun Shopping - A Randomized Field Experiment of Gamification**

Yi-Jen (Ian) Ho, Pennsylvania State University, 465 Business Building, Smeal College of Business, University Park, PA, 16802, United States, Siyuan Liu, Lei Wang

In this research, we conduct a large-scale randomized field experiment at one of the largest Asian shopping mall to investigate the impact of gamification on customer engagement. The results shows gamification not only user engagement in terms of time spent and distance walked, but increase stores' sales. We further benchmark this impact with the effect of traditional couponing. This study provides important implications on how firms can take advantages of gamification.

**5 - The Effect of Search Costs and Stockouts on Consumer Search Behavior and Price Competition**

Xingyue (Luna) Zhang, University of Washington Tacoma, 621 Taylor Street, Tacoma, WA, 98402, United States, James Dearden, Yuliang Yao

Consumers face various costs during shopping: the travel costs to visit stores and the search cost to examine product attributes once at a store. We build game-theoretic models and examine the interaction between store pricing and consumer search behavior with different costs. Our findings suggest that: 1) stores set equilibrium prices higher than marginal costs with the existence of the travel and search costs as well as stockout probabilities, 2) following product stockouts, stores are better off by giving up consumers when the attribute search cost is high, and 3) consumers are less likely to visit a store when the costs and/or stockout probabilities are high such that the prices are lower.

**■ TB68**

West Bldg 105C

**High Dimensional Data Analytics for Smart and Connected Systems**

Sponsored: Quality, Statistics and Reliability

Sponsored Session

Chair: Raed Al Kontar, University of Wisconsin-Madison, Madison, WI, 53706, United States

Co-Chair: Chenang Liu, Blacksburg, VA, 24060, United States

**1 - Minimizing Negative Transfer of Knowledge in Multivariate Gaussian Processes: A Scalable and Regularized Approach**

Raed Al Kontar, University of Wisconsin-Madison, Madison, WI, 53706, United States

We propose a regularized and scalable modeling approach for the multivariate Gaussian process established using a convolution process. The key feature of our approach is the ability to minimize the negative transfer of knowledge between uncorrelated output through penalizing latent functions that facilitate information sharing. Statistical guarantees for the proposed method are studied and its advantageous features are demonstrated through numerical studies.

**2 - A Multiplex Network Modeling Approach for Online Process Monitoring**

Chenang Liu, 845 Claytor Square, Blacksburg, VA, 24060, United States, Zhenyu Kong

The objective of this research is to implement a new online monitoring method for complex systems using high dimensional sensing data. To achieve this objective, a multiplex network-based modeling approach is proposed in this study. The novelty of this method is to describe the sensing data using an effective multiplex network structure. Case studies in manufacturing and healthcare applications demonstrate that the proposed method can significantly enhance the monitoring sensitivity compared to the conventional methods.

**3 - Deterministic and Stochastic Data Decomposition for Analytics of Complex Systems**

Xiaowei Yue, Georgia Institute of Technology, 755 Ferst Drive NW, ISYE, Atlanta, GA, 30332, United States, Jianjun Shi

Data decomposition is an important step for high-dimensional data analytics of complex systems. This paper summarizes the key techniques for data decomposition, and separates them into two categories. One is deterministic decomposition, and the other is stochastic decomposition. The deterministic decomposition captures geometric or algebraic shape from the high-dimensional datasets directly, which is efficient for feature extraction and dimensionality reduction; while the stochastic decomposition provides probabilistic descriptions, and statistical distributions are estimated from the datasets.

#### 4 - Wavelet-based Profile Monitoring using Order-thresholding Recursive CUSUM Schemes

Ruizhi Zhang, Georgia Institute of Technology, Atlanta, GA,  
United States, Yajun Mei, Jianjun Shi

With the rapid development of advanced sensing technologies, rich and complex real-time profile or curve data are available in many manufacturing processes. These profile data provide valuable intrinsic information about the performance of the process, subject or product, and it is often desirable to utilize them to develop efficient methodologies for process monitoring and fault diagnosing. In this article, we propose a novel wavelet-based profile monitoring procedure that is based on the order-thresholding transformation of recursive CUSUM statistics of multiple wavelet coefficients. Simulation and case study are conducted to illustrate the usefulness of our proposed procedure.

#### ■ TB69

West Bldg 106A

#### Large Scale Statistical Learning

General Session

Chair: Meisam Razaviyayn, University of Southern California,  
Los Angeles, CA, 90089, United States

##### 1 - Learning Bounds for Greedy Approximation with Multiple Explicit Feature Maps

Shahin Shahrampour, Texas A&M University, College Station, TX,  
United States

Large-scale Mercer kernels can be approximated using low-dimensional feature maps for efficient risk minimization. Due to the inherent trade-off between the feature map sparsity and the approximation accuracy, the key problem is to identify promising feature map components (bases) leading to satisfactory out-of-sample performance. In this work, we tackle this problem by efficiently choosing such bases from multiple kernels in a greedy fashion. Our method sequentially selects these bases from a set of candidate bases using a correlation metric. We prove that the out-of-sample performance depends on three types of errors, one of which (spectral error) relates to spectral properties of the best model in the Hilbert space associated to the combined kernel. The result verifies that when the underlying data model is sparse enough, i.e., the spectral error is negligible, one can control the test error with a small number of bases, scaling poly-logarithmically with data. Our empirical results show that given a fixed number of bases, the method can achieve a lower test error with a smaller time cost, compared to the state-of-the-art in data-dependent random features.

##### 2 - Valid p-values from Adaptively Collected Data

Yash Deshpande, Massachusetts Institute of Technology,  
Cambridge, MA, United States

Data collection in many scientific and engineering applications is inherently adaptive. For instance, sequential or multi-stage clinical trials may reallocate patients among different treatments based on data gleaned from previous stages. In e-commerce applications, most user behavior data is collected under feedback from recommendation algorithms that are continuously trained. Such adaptivity is problematic for ex post inference, causing standard statistical techniques to fail. We propose a novel decorrelating procedure that correct standard estimators for adaptivity. The procedure is model-free: it requires only coarse information about the data-collection algorithm, in comparison with competing procedures like propensity scores. Therefore, it enables computing ex post valid p-values and confidence intervals on adaptively collected data.

##### 3 - On the Importance of Being Improper in ML

Karthik Sridharan, Cornell University, Ithaca, NY, United States

This talk will focus on the benefits of improper learning (where predictor can lie outside model class) when dealing with machine learning problems. Be it from the perspective of computational efficiency, sample complexity or both. The first part of the talk will focus on sample complexity. We will specifically focus on logistic regression and starting with the simple observation that the logistic loss is 1-mixable, we design a new efficient improper learning algorithm for online logistic regression that circumvents the aforementioned lower bound with a regret bound exhibiting a doubly-exponential improvement in dependence on the predictor norm. This provides a positive resolution to a variant of the COLT 2012 open problem of McMahan and Streeter (2012) when improper learning is allowed. The second part of the talk will focus on computational advantages of improper learning.

##### 4 - Randomized Algorithms for Infinite Dimensional Optimization Problems

Cameron Musco, Massachusetts Institute of Technology,  
Cambridge, MA, United States

We will discuss recent advances in randomized algorithms for infinite dimensional optimization problems that arise in kernel-based machine learning. Kernel-based learning is notoriously difficult to scale to large datasets because the runtime of exact methods typically scales quadratically in the number of data points. Many techniques have been suggested to reduce this cost, including Rahimi and Recht's random Fourier features method and the Nyström method, which both rely on random sampling to obtain approximately optimal solutions.

#### ■ TB70

West Bldg 106B

#### Joint Session DEA/Practice Curated: Theoretical issues in DEA

Emerging Topic: Productivity, Efficiency and Data Envelopment Analysis

Emerging Topic Session

Chair: Peter Bogetoft, Frederiksberg, 2000, Denmark

##### 1 - Rate Design and Grid Efficiency

Jung Sook You, Assistant Professor, California State University-East Bay, 25800 Carlos Bee Blvd, Hayward, CA, 94542, United States

Time-dependent consumer preferences combined with intermittent renewable energy sources may result in excess demand fluctuations on a power grid network. Assuming consumers and generators can be price-anticipating strategic players, this paper derives the optimal locational marginal prices on the power grid with conventional and renewable generators and provides theoretical prediction of price volatility. Then, the paper simulates the extent to which the optimal locational prices respond to the volatility of renewable sources and consumer demands, using California wholesale market data.

##### 2 - Benchmarking, Contracting, and Incentive Power

Peter Bogetoft, Copenhagen Business School, Porcelaenshaven 16 A, Frederiksberg, 2000, Denmark

Benchmarking is a popular management tool. It is used both to facilitate decision making and incentive provision. In this paper, we show that different benchmarking measures react differently to changes in performance. Therefore, the optimal design of benchmarking based performance contract requires an explicit analysis of the data generation process of the benchmarking approach. As an illustrative application, we investigate the use of Data Envelopment Analysis (DEA), Stochastic Frontier Analysis (SFA) and combinations thereof in revenue cap incentive schemes. Such schemes are applied in the regulation of network companies in many countries.

#### ■ TB71

West Bldg 106C

#### ICS Student Paper Prize

Sponsored: Computing

Sponsored Session

Chair: Anna B. Nagurney, University of Massachusetts-Amherst, Isenberg School of Management, Dept of Operations & Information Mgmt, Amherst, MA, 01003, United States

##### 1 - Fortification Against Cascade Propagation Under Uncertainty

Colin P. Gillen, University of Pittsburgh, 1025 Benedum Hall, 3700 O'Hara Street, Pittsburgh, PA, 15261, United States

Network cascades represent a number of real-life applications: social influence, electrical grid failures, viral spread, etc. The commonality between these phenomena is that they begin from a set of seed nodes and spread to other regions of the network. We consider a critical elements detection problem where the decision-maker wishes to limit cascading behavior via node threshold modification (within a budget). The arc weights - how much influence one node has on another - are uncertain. The solution approaches include robust mixed-integer programming, an expand-and-cut algorithm, and centrality-based heuristics. Extensive computational experiments demonstrate the value of these methods.

##### 2 - V-Polyhedral Disjunctive Cuts

Aleksandr M. Kazachkov, Carnegie Mellon University, Tepper School of Business, 5000 Forbes Avenue, Pittsburgh, PA, 15213-3890, United States

We introduce V-polyhedral cuts (VPCs) for generating strong disjunctive inequalities, with the goal of mitigating numerical issues in existing cuts by avoiding recursion. The VPC framework involves collecting a properly selected set of points and rays. This affords computational advantages over existing methods and enables testing strong multiterm disjunctions arising from partial branch-and-bound trees. Our computational and theoretical results suggest the potential practical benefits of VPCs, while motivating future work on better understanding the interaction between branching and cutting.

### 3 - Asymptotically Optimal Exact Solution of Sparse Linear Systems via Left-Looking Roundoff-Error-Free LU Factorization

Christopher Lourenco, Texas A&M University, 999 West Villa Maria Road, Apt 607, Bryan, TX, 77801, United States

LU factorizations are the key tool used to solve sparse systems of linear equations (SLEs) arising in linear/integer programming. However, roundoff errors, accrued while solving SLEs, may lead solvers to claim suboptimal bases as optimal, feasible problems as infeasible, or vice versa. To address this, we develop an exact LU factorization with 3 key properties: 1) only integral operations, 2) polynomially bounded entry size in L and U, and 3) asymptotically optimal computational complexity. Also we computationally show that the new LU factorization outclasses a modern rational solver for SLEs.

## ■ TB72

West Bldg 211A

### Security Informatics

General Session

Chair: Victor Benjamin, University of Arizona, Tempe, AZ, United States

#### 1 - Detecting Cyber Threats in Non-english Dark Net Markets: A Cross-lingual Deep Learning Approach

Mohammadreza Ebrahimi, University of Arizona, Tucson, AZ, 85719, United States, Hsinchu Chen

Dark Net Markets (DNMs) provide hackers with highly-specialized tools that may not be found in other platforms in hacker community. While text classification techniques have been used for cyber threat detection in English DNMs, the task is hindered in non-English platforms due to the language barrier and lack of ground-truth data. Current methods use machine translation with monolingual models to address these challenges. However, the translation errors can deteriorate the classification results. We show that a cross-lingual model that uses two languages, significantly outperforms a monolingual model learned on machine translated data for detecting cyber threats in non-English DNMs.

#### 2 - Avatar Image Role in Developing Trust in an Intelligent Cybersecurity Agent

Troy Adams, University of Arizona, Tempe, AZ, United States, Gondy Leroy

Intelligent agents are used in a variety of applications and have made their appearance in modern networking and security technologies. In cybersecurity, these agents provide alerts and solutions for mitigating threats to a network, as well as training. This study aims to understand the development of trust in an intelligent cybersecurity agent (ICA), based on the image displaying its avatar. Results indicate that an avatar image had an impact on trust development for an ICA, especially for women. This research adds to IS literature by highlighting the role appearance has in improving HCI.

#### 3 - Deep Learning for Text-based Social BOT Detection

Victor Benjamin, Arizona State University, Tempe, AZ, United States, Raghu Santanam

Dark Net Markets (DNMs) provide hackers with highly-specialized tools that may not be found in other platforms in hacker community. While text classification techniques have been used for cyber threat detection in non-English DNMs, the task is hindered in non-English platforms due to the language barrier and lack of ground-truth data. Current methods use machine translation with monolingual models to address these challenges. However, the translation errors can deteriorate the classification results. We show that a cross-lingual model that uses two languages, significantly outperforms a monolingual model learned on machine translated data for detecting cyber threats in non-English DNMs.

## ■ TB73

West Bldg 211B

### JFIG Panel Discussion: Becoming a More Productive Writer

Sponsored: Junior Faculty JFIG

Sponsored Session

Chair: Chrysafis Vogiatzis, North Carolina A&T State University, Greensboro, NC, 27411, United States

Co-Chair: Gokce Palak, Shenandoah University, Winchester, VA, 22601, United States

#### 1 - JFIG Panel Discussion: Becoming a More Productive Writer

Chrysafis Vogiatzis, North Carolina A&T State University, 1601 East Market Street, McNair 405, Greensboro, NC, 27411, United States

Panelists will share their experiences, and provide insights on how to become a more productive writer. The goal of the session is to introduce tips and pitfalls for

new assistant professors (and other researchers in the beginning of their careers) when it comes down to academic writing, broadly defined (research publications, grant proposal writing, outreach and general population).

#### Panelists

Laura Albert, University of Wisconsin-Madison, Industrial & Systems Engineering, 1513 University Avenue, Madison, WI, 53706, United States

Halit Uster, Southern Methodist University, Lyle School of Eng., Dept. EMIS, Dallas, TX, 75275-0123, United States

Lawrence V. Snyder, Lehigh University, Mohler Lab 200 West Packer Avenue, Bethlehem, PA, 18015-1582, United States

Elise Miller-Hooks, George Mason University, 208 Rosalie Cove Ct, Silver Spring, MD, 20905, United States

## ■ TB74

West Bldg 212A

### Joint Session MCDM/Practice Curated: Multi-Objective Simulation Optimization and its Applications

Sponsored: Multiple Criteria Decision Making

Sponsored Session

Chair: Susan R. Hunter, Purdue University, West Lafayette, IN, 47907-2023, United States

#### 1 - Digital Twin for the Smart System

Loo Hay Lee, National University of Singapore, 10 Kent Ridge Crescent, Industrial and Systems Engineering, Singapore, 119260, Singapore

In this talk, we will share the digital twin system we have built for the port system and warehouse system, and will discuss how the simulation optimization technique is able to help to design the system.

#### 2 - Indifference Zones in Multi-Objective Ranking & Selection

Juergen Branke, University of Warwick, UK, Warwick Business School, Orms Group, Coventry, CV4 7AL, United Kingdom, Wen Zhang

Multi-objective ranking and selection so far has mostly focused on probability of correct selection as criterion. However, this creates problems if there are two very similar solutions, as many samples would be needed to correctly classify them. Thus, people have proposed to allow for an indifference zone, describing a decision maker's indifference between very similar solutions. We demonstrate that a previously proposed concept of indifference zones in multi-objective problems has some drawbacks, and propose an alternative definition. We also show how this can be used as part of a myopic ranking and selection technique.

#### 3 - Bi-objective Simulation Optimization on Integer Lattices using the Epsilon-constraint Method in a Retrospective Approximation Framework

Susan R. Hunter, Purdue University, School of Industrial Engineering, Grissom Hall, 315 N. Grant Street, West Lafayette, IN, 47907-2023, United States, Kyle Cooper, Kyle Cooper, Kalyani S. Nagaraj

We propose the Retrospective Partitioned Epsilon-constraint with Relaxed Local Enumeration (R-PerLE) algorithm to solve the bi-objective simulation optimization problem on integer lattices. R-PerLE uses a retrospective approximation (RA) framework to repeatedly call the PerLE algorithm at a sequence of increasing sample sizes. Within an RA iteration, the PerLE algorithm uses the e-constraint method to add new sample-path local efficient points to the estimated local efficient set (LES). Then, it certifies the estimated LES is approximately a sample-path LES. As the number of RA iterations increases, R-PerLE provably converges to a LES wpl.

#### 4 - Multiple Objective Probabilistic Branch and Bound for Multi-fidelity Simulation Optimization

Hao Huang, Yuan Ze University, IEM Department, Yuan Ze University, 135 Yuan-Tung Road, Chung-Li, Taoyuan, 32003, Taiwan,

Multi-fidelity framework involves simulation optimization problems involving multiple models with different fidelities, such as an accurate but costly simulation and a quick approximation. A multiple objective simulation algorithm is proposed in this study for the multi-fidelity framework, named Multi-Fidelity and Multi-Objective Probabilistic Branch and Bound (MFOPBnB). MFOPBnB incorporates Multiple Objective Probabilistic Branch and Bound (MOPBnB), a partition-based simulation optimization algorithm approximates the Pareto optimal set. Using information from low fidelity model, MFOPBnB approximates the a Pareto optimal set with statistical quality derived.



## 5 - Simulation-based Optimization in Outpatient Appointment Scheduling

Payman Jula, Associate Professor, Simon Fraser University,  
Faculty of Business, Vancouver, BC, V5A 1S6, Canada

This talk addresses the challenges of outpatient scheduling in multi-stage healthcare facilities. We consider stochastic service times, the availability and compatibility of resources, and the presence of a variety of patient types. The proposed methods are based on integrating simulation with mathematical programming, and meta-heuristics algorithms to achieve multi objectives of minimizing the waiting time of patients, the completion time of the facility, and the procedures cancellation. The performance of proposed approaches are analyzed an reported.

## ■ TB75

West Bldg 212B

## Operations Research at USAFA

General Session

Chair: Megan Muniz, USAFA, Monument, CO, 80132, United States

### 1 - Air Force Business Process Automation

Mark J. Williams, USAFA

The Air Force has numerous processes operated by humans where modern service management systems could streamline their execution. This research analyzes processes used throughout the Air Force to develop improved workflows, identify areas to automate, and implement them using a modern service management system. The overarching goals of this research effort are to streamline Air Force business processes into a single, consistent look and feel, eliminate duplicate licenses and associated licensing costs, save manpower through improved process automation, and improve business process tracking and transparency.

### 2 - Cadet Summer Research Program

Drew X. Richardson, Colorado Springs, CO, 80920, United States

At the United States Air Force Academy, elite students are chosen to participate in the competitive Cadet Summer Research Program. What makes the program selective is that a cadet can only participate between his/her junior and senior year. Those selected are granted the opportunity to do research at military installations such as the Pentagon or Hickam Air Force Base, HI, as well as work with non-DoD agencies such as the NSA or the DHS. In addition, cadets can also work for defense contractors such as the Institute for Defense Analysis or with companies like Facebook. This talk provides an overview of the selective CSRP process, and a snapshot at some of the high quality research performed by USAFA cadets.

### 3 - Analysis From the United States Air Force Academy's Operations Research Capstone Course

Gregory Steeger, USAFA, 16932 Park Trail Drive, Monument, CO, 80132, United States

At USAFA, OR Majors take a year-long Capstone. In this culminating course, students analyze and solve problems faced by real clients, using the analytical skills they have acquired over the previous three years. Last year, 36 students worked in teams of four for nine clients. Clients included a tissue bank; Air Force Reserve Command Recruiting Service; Air Force Special Operations Command; Air Mobility Command; the Children's Hospital of Colorado; Lockheed Martin; the National Geospatial Intelligence Agency; Sandia National Labs; and USAF Personnel. This talk provides an overview of the nine problems these 36 students analyzed and discusses the results they delivered to their clients.

### 4 - Optimal Configurations for Mountain Switchbacks

Kristopher Pruitt, United States Air Force Academy, 2 Grass Song Place, Monument, CO, 80132, United States

The purpose of this research is to determine the configuration (number, length, and gradient) of paths (i.e., switchbacks) that minimizes the time or energy required for a hiker to ascend a mountain face. We present a mathematical model of the possible path configurations and nonlinear optimization problems which select the optimal paths. The model is parameterized according to the dimensions of the mountain face and the physiological capabilities of the hiker. Subject to these parameters, the optimization problems return the path-gradient and length required for a hiker to minimize either the time or energy to ascend the face.

### 5 - Faculty Summer Research

Megan Muniz, USAFA, CO Springs, CO, United States

Currently, the Air Force (AF) is experiencing a pilot shortage, where the operational tempo's demand for combat pilots exceeds supply. Retention efforts to date have been insufficient to solve this problem. Pilot Training Next (PTN) is the AF's experimental investigation into two possible responses to the current pilot shortage: increasing Undergraduate Pilot Training throughput and increasing the pool of qualified pilot candidates. A group of pilots will go through a modified training syllabus; IDA and USAFA faculty member is analyzing the data to determine what factors facilitated more efficient learning and skill acquisition with the aim of creating a model of pilot training effectiveness.

## ■ TB76

West Bldg 212C

## Joint Session PSOR/Practice Curated: OR Applications in Humanitarian Logistics

Sponsored: Public Sector OR

Sponsored Session

Chair: Hafizul Islam, North Carolina State University, Raleigh, NC, 27695, United States

### 1 - Modeling the Logistics Capabilities of Home Health Agencies to Provide In-home Dispensing to Vulnerable Populations During Public Health Emergencies

Ashlea Bennett Milburn, University of Arkansas, 4207 Bell Engineering Center, Fayetteville, AR, 72701, United States,  
Emre Kirac, Charleen McNeill

Public health emergencies may call for medical countermeasures dispensing to affected populations. Many people can visit established dispensing locations en masse, but this is impractical for vulnerable homebound populations. Home health agencies (HHAs) have potential to act as private dispensing entities in this situation, treating homebound persons and their families in their homes. This research establishes the comparative effectiveness of centralized and decentralized operational models of in-home dispensing via HHAs. Results are presented for a mixed urban/rural case study area.

### 2 - An Integer L-shaped Algorithm for the Integrated Location and Network Restoration Problem in Humanitarian Relief

Ece Sanci, University of Michigan, Ann Arbor, MI, United States,  
Mark Stephen Daskin

Prepositioning emergency relief items before an anticipated disaster is a common strategy to increase the effectiveness of relief distribution. In this study, we assume that relief distribution is hampered due to damaged roads. We present a two-stage stochastic programming model integrating facility location and network restoration decisions. We propose an integer L-shaped algorithm which deploys lower and upper bounds to solve our model efficiently. Our computational results show significant improvement in unmet demand and cost measures by integrating location and network restoration models.

### 3 - Dynamic Network Flow Problems Having ARC Setup Costs

Rob Curry, Clemson University, Cole Smith

Some network applications require dynamic flows to be transmitted according to a non-simultaneous schedule. In this talk, we consider a dynamic network flow problem that considers the presence of arc setup costs that may exist whenever an arc begins transmitting flow. This problem can be modeled by the minimum cost flow problem having arc-activation costs (MCF-A), in which an arc (i,j) is said to be activated on a path p when (i,j) is included on p but not on p-1. As an alternative to this mixed-integer programming approach, we employ a relaxation-based algorithm for obtaining upper and lower bounds that increases the number paths in a schedule, as needed.

### 4 - Robust Optimization Approaches for the Equitable and Effective Distribution of Donated Food

Irem Sengul Orgut, Lenovo, 8209 Pritchett Farm Lane, Raleigh, NC, 27606, United States, Julie Simmons Ivy, Reha Uzsoy, Charlie Hale

Motivated by our partnership with a local food bank, we present a robust optimization model to support the equitable and effective distribution of donated food over the service area. Our model addresses uncertainty in the amount of donated food counties can receive. Letting the capacity of each county vary within a range, the model seeks to maximize total food distribution while enforcing a user-specified level of robustness. We derive structural properties and develop an efficient exact solution algorithm. We illustrate our model using historical data obtained from our food bank partner, summarize the policy implications of our results and examine the impact of uncertainty on outcomes.

### 5 - A Dynamic Programming Approach for Equitable and Effective Distribution under Uncertain Supply

Md Hafizul Islam, North Carolina State University, 111 Lampe Drive, Daniel Hall 373, Raleigh, NC, 27695, United States,  
Julie Simmons Ivy

Food banks in the United States serve people in hunger need within their respective service regions with donated food. Food banks receive donations from various sources and distribute them in an equitable and effective manner. Uncertainty in food donations is a big challenge for food banks in planning the distributions of food donations for future periods. In this work, we present a Markov decision process model and a dynamic programming solution approach of the model to deal with the uncertain supply for a local food bank over a finite number of periods with an aim to make an equitable and effective distribution of donated food.

## ■ TB77

West Bldg 213A

### Emergency Response II

Sponsored: Public Sector OR

Sponsored Session

Chair: Forough Enayaty Ahangar, University of Wisconsin-Madison, Madison, WI, 53706, United States

Co-Chair: Laura Albert, University of Wisconsin-Madison, Industrial & Systems Engineering, 1513 University Avenue, Madison, WI, 53706, United States

#### 1 - Improving the Resiliency of a State Trauma System

Eric DuBois, University of Wisconsin-Madison, Industrial & Systems Engineering, 1513 University Avenue, Madison, WI, 53706, United States, Benjamin Morris, Laura Albert

On average, rural trauma patients can currently expect longer average pre-hospital times and worse outcomes compared to their urban counterparts. In addition, rural responders are more easily overwhelmed by surges in demand. To address these concerns, we develop a stochastic capacitated coverage model to examine where to deploy and upgrade resources with a goal of decreasing pre-hospital times, providing greater access to high-level trauma care, and ensuring adequate backup coverage in the event of mass-casualty incidents. Computational examples drawn from motor vehicle crash data are used to demonstrate the model.

#### 2 - Maximal Multiple Coverage and Network Restoration Problem for Disaster Recovery

Suzan Iloglu, Graduate Student, University of Wisconsin-Madison, 1611 Monroe St Apt 410, Madison, WI, 53711, United States

Repairing network damage in road infrastructure is important for enabling the delivery of time-sensitive response services after a disaster. To address this issue, we present an extension of the maximal multiple coverage problem that coordinates the services of network recovery crews and emergency responders. The proposed model is composed of three components: (1) network restoration, (2) relocation of emergency responders with restricted access and (3) coverage of emergency demand. The objective maximizes the coverage of emergency demand over the time horizon. Two different heuristics are presented to construct high quality feasible solutions to the problem and tested using real world data.

#### 3 - Modeling and Analysis in Tele-ICU Setting: Intervention with Preemptive Priorities

Xuanjing Li, Tsinghua University, Room 519, ShunDe, Beijing, China, Xiaolei Xie, Muer Yang, Michael Fry, Dacheng Liu, Corey Scurlock

Tele-ICU is a novel approach to provide critical care remotely along with the bedside ICU team. We investigate optimal staff capacity and scheduling policies using both analytical and simulation models based on a real case. We also provide managerial insights regarding dedicated staff and flexible staff in the Tele-ICU.

## ■ TB78

West Bldg 213B

### Alternative-Fuel Vehicles Refueling and Routing Problems I

Sponsored: Location Analysis

Sponsored Session

Chair: Ismail Capar, Texas A&M University, College Station, TX, 77843-3367, United States

Co-Chair: Yudai Honma, The University of Tokyo, Tokyo, 153-8505, Japan

#### 1 - Bender Decomposition for Large-scale Flow-refueling Location Model

Ibrahim Capar, Bowling Green State University, Department of ASOR, 355 Business Administration Building, Bowling Green, OH, 43403, United States, Ismail Capar

In this research, we propose a Bender Decomposition formulation to solve flow-refueling location model for alternative fuel vehicles. We improve the standard formulation through a multi-cut reformulation that uses a path based clustering to accelerate its convergence. We discuss the performance of the method in detail and share the results from extended numerical experiments.

#### 2 - Deviation Distance and Sufficient Density of Alternative Fuel Stations

Masashi Miyagawa, University of Yamanashi, 4-4-37, Takeda, Kofu, 400-8510, Japan

This paper presents a model for determining the sufficient density of alternative fuel stations. To incorporate both flow demand and the deviation distance, the service level is represented as the probability that the vehicle can make the repeated round trip between randomly selected origin and destination within a specified deviation distance. The density of stations required to achieve a certain level of service is obtained for three cases of the refueling availability at origin and destination. The result shows how the deviation distance, the vehicle range, the trip length, and the refueling availability at origin and destination affect the sufficient density of stations.

#### 3 - Routing Management Strategy for New Collaborative Platform for Japanese Municipalities

Tsuyoshi Nobata, Tokyo University of Tokyo, Ce-408, 4-6-1, Komaba, Tokyo, Japan, Shuto Tsuchiya, Yudai Honma

New collaborative platform for Japanese municipalities has been developed to integrate both the worker's and citizen's knowledge. As one of the functions in the platform, optimal schedule management tool has been implemented. In this presentation, we discuss the optimal routing strategies to determine day tour routes for multiple maintenance vehicles. The formulation is based on multiple traveling salesmen problems, so has high similarities with AFV routing behaviors.

#### 4 - An Exact Solution to Profit Maximizing Electric Vehicle Routing Problem

Isil Koyuncu, The University of Alabama, Tuscaioosa, AL, 35406, United States, Mesut Yavuz

This talk presents a maximum profit mixed fleet electric vehicle routing problem. A mixed fleet consists of traditional gasoline or diesel and electric vehicles. Electric vehicles enable the fleet operator to reduce their operating costs as well as carbon emissions. In addition, a set of customers are willing to pay a premium to receive service by electric vehicles to reduce their supply chain carbon footprint. We formulate the emerging problem as a mixed integer linear program and present an exact solution methodology as well as their computational evaluation from our preliminary experiment.

## ■ TB79

Hyatt, Curtis A

### Supply Chain Management III

Contributed Session

Chair: Sima Sabahi, North Carolina A&T State University, 704-1C Granite Street, Greensboro, NC, 27403, United States

#### 1 - Multi-product Supply Network with an Intermediary

Omkar D. Palsule-Desai, Faculty, Indian Institute of Management Indore, Indore, 453331, India

We develop game theoretic models to characterize equilibrium outcomes for competing firms in a decentralized network setting with diverse objectives. We examine implications for maintaining private products while supplying a shared product in a geographically segregated market. The firms respond to both horizontal and vertical competition in the network. Our significant contribution to the existing literature is in showing that a supply network of competing firms can survive under certain situations with the firms simultaneously supplying to their private products along with the shared product of the network.

#### 2 - Negotiation under Competition Comparison between Nash and Kalai Smorodinsky Bargaining Framework

Yuanchen Li, Purdue University, 2192 Tortuga Lane, West Lafayette, IN, 47906, United States, Qi Feng, J. George Shanthikumar

We study the difference between the Kalai-Smorodinsky (KS) and Nash Bargaining (NB) framework in a two-tier supply chain. We find that the KS solution can lead to a more reliable negotiation outcome when contingency terms are imposed, compared to the NB solution.

#### 3 - Investigating the Relationship Between Supply Chain Resilience and Innovation Through Fuzzy Cognitive Mapping

Sima Sabahi, PhD Candidate, North Carolina A&T State University, 1601 East Market St., Greensboro, NC, 27411, United States, Paul M. Stanfield

In today's turbulent environment, an understanding of how firms can manage supply chain disruptions and improve their resiliency has become a critical subject. One of the capabilities enabling companies to overcome disruptions, and adapt to rapid changes in the environment is allocating priority and resources to innovation. Although innovation has been viewed as a key component of a firm's long-term survival and development, the impact of innovation in improving resiliency in supply chain has been relatively disregarded. This study provides a flexible, quantitative model of the causal relationship between supply chain resilience and innovation capability through fuzzy cognitive mapping.

#### 4 - A General Dual Sourcing Inventory Model: Trading off Lead Time and Cost Differences

Zhe Liu, Columbia Business School, 3022 Broadway, New York, NY, 10027, United States, Awi Federgruen, Lijian Lu

We study a single product, periodic review inventory system with two suppliers and salvage options. A regular supplier has a longer lead time but is cheaper than an expedited supplier. Salvage options allow for bilateral inventory adjustments. All inventory adjustments involve a fixed cost component in addition to variable costs or revenues and may be capacitated. We show that the optimal order sizes and/or salvage quantity follow a relatively simple structure. This applies when the lead times of the two suppliers differ by a single period. However, our structural results suggest effective heuristics for general lead times and demonstrate the significant benefits of dual sourcing.

#### 5 - Inventory Inaccuracies and Radio Frequency Identification Technology: Risk Analysis and Coordination

Tingting Wang, Huazhong University of Science & Technology, No. 1037, Luoyu Road, Hongshan District, Wuhan, 430074, China

We study the adoption of RFID to reduce the inventory shrinkage and misplacement in the supply chain, which consists of a risk-neutral manufacturer and a risk-averse retailer. The Conditional Value at Risk criterion is adapted to measure the retailer's risk attitude. We focus on exploring how the risk attitude affects the agents' incentives and show that the incentives to adopt RFID depend on the risk attitude. Further, when the tag cost is sufficiently low, the agents' incentives increase with the risk-averse level increasing. Additionally, the supply chain can afford higher tag cost (fixed cost) if the retailer is more risk-neutral. Finally, we also identify the coordination mechanism under RFID.

## ■ TB80

Hyatt, Curtis B

### Practice- Supply Chain Management V

Contributed Session

Chair: Devaraja Vignesh Radha Krishnan, Oklahoma State University, Stillwater, OK, 74075, United States

#### 1 - Reduce Carbon Emissions Across Supply Chain: The Role of Information Sharing

Sijie Zhou, Doctoral Student, University of Science and Technology of China, No.96 JinZhai Road, Baohe District, Hefei, 230026, China, Yugang Yu

This study is motivated by a few international retailers (like, Walmart and H&M) cooperating with their suppliers to reduce carbon emissions across the supply chains. Our paper investigates the operations associated with information sharing and studies its influence on environment under the real condition. We show that with Bayesian updating of demand, information sharing will benefit supplier but possibly hurt retailer. We reveal the conditions favoring information sharing: information sharing doesn't always benefit the environment, which contradicts to the popular thoughts about the advantage of collaborative contracts between retailers and suppliers.

#### 2 - Does Vertical Integration Allow for More Sustainable Supply Chain? Comparative Analysis within the Apparel Manufacturing Industry

Suri Gurumurthi, Hong Kong University of Science and Technology, Clearwater Bay Road, Kowloon, Hong Kong, HK, Ronald Lau

Through this research, we aim to investigate whether the vertically integrated supply chain can perform better along limited sustainability metrics, as compared to the network or decentralized model of sustainability. We also explore the linkage between vertical integration and targeted technology investment towards sustainability performance. We also comment on how incentives are relatively harder to align in decentralized structures, and the specific role of incentives in sustainability performance.

#### 3 - Impact of Social and Environmental Performance Assessment of Suppliers on Buyer Supplier Relationship and Purchasing Performance

Sivamanikarthy Rajendran, Research Scholar, Indian Institute of Technology Madras, Sardar Patel Road, Opposite to C.L.R.I, Adyar, Chennai, 600036, India, Arshinder Kaur

In this study, we contribute to the existing line of literature by identifying the key social and environmental factors in the Indian context based on an exhaustive review of literature and analyzing the impact of social and environmental performance assessment of suppliers on the purchasing performance of the buying firm. We also study this impact when the focal firm is utilizing supply chain analytics (which acts as a moderating variable). Finally, we develop a conceptual framework based on the underlying relationships between the above mentioned variables which will aid the managers in understanding how social and environmental performance evaluation influences the purchasing performance.

#### 4 - Freight Consolidation Problem with Pickup and Delivery Sequence and Loading Constraints

Devaraja Vignesh Radha Krishnan, Oklahoma State University, Stillwater, OK, 74075, United States, Tieming Liu

In Pickup and Delivery problem (PDP), if multiple shipments are consolidated and placed in a vehicle, then the loading order of shipments is a major cost factor along with the trip distance. We address the PDP with the Last-In-First-Out (LIFO) order for pickup and delivery of shipments. In addition, we relax the LIFO constraints and present an exact formulation and algorithms for PDP with LIFO violation penalties.

## ■ TB81

Hyatt, Phoenix East

### Optimization II

Contributed Session

Chair: Roya Ghorashi, University of Wisconsin-Milwaukee, P.O. Box 413, Milwaukee, WI, 53211, United States

#### 1 - Integrating Nesting and Cutting Path Determination Problems

Larissa Oliveira, University of Sao Paulo, 400 Trabalhador São-carlense Avenue, Sao Carlos, 13566-590, Brazil, Franklina Toledo, Jos Fernando Oliveira

The nesting problem consists of finding a layout for small irregular shaped pieces that must be cut from a larger object with fixed height and infinite length, minimizing the length required to cut all the pieces. In some industries, after a solution of this problem has been defined, a second problem arises: the determination of the cutting path, i.e. to determine the shortest path length required to cut all the pieces. The solution of the first problem strongly influences the resolution of the second. To tackle this joint problem, we propose an integrated approach.

#### 2 - Synchronizing Last Trains of Urban Rail Transit System to Better Serve Passengers from Late Trains of High-Speed Railway Lines

Sihui Long, Beijing Jiaotong University, Beijing, China, Lingyun Meng, Xi Jiang, Yuyan Tan, Francesco Corman

This paper develops a bi-objective mixed-integer linear model for the problem of last-train timetable synchronization of urban rail transit (URT) system to better serve passengers from late trains of high-speed railway lines in late night. The bi-objective optimization problem is to maximize the number of passengers who can arrive their destinations successfully and to minimize the total operation-ending time for last trains of URT system. This model can deliver both a last-train transfer scheme solution and a last-train timetable of URT system at the same time. The  $\epsilon$ -constraint method is used to find the Pareto optimal solutions for the proposed bi-objective model.

#### 3 - Developing a Continuous Location Routing Model

Ali Sarabi, Arizona State University, Tempe, AZ, United States, Adolfo Raphael Escobedo

Generally, the costs of logistics and distribution make up a significant share of a product's price. As a result, integration of location and routing decisions has great potential to reduce total costs. How these decisions can be made simultaneously has been widely studied for locations in a discretized space but few works have considered a continuous space. In this study, we develop an MIP model and solution methodology for the capacitated location routing problem (CLRP) for this context. Specifically, the space is segmented and location priorities are considered by allocating construction costs by zones, and then impossible location cases are removed from the potential decisions.

#### 4 - Math Models and Heuristic Methods for Constructing Fair Political Districts

Roya Ghorashi, PhD Candidate, University of Wisconsin-Milwaukee, 2615 N. Cramer Street, # 39, Milwaukee, WI, 53211, United States, Matthew E. Petering

Political district maps are crucial to a fair distribution of political power. This study attempts to find a solution to form fair political districts considering various criteria. We propose several exact and heuristic methods for creating fair political districts. Preliminary results indicate that these methods produce political district maps of high quality.



## ■ TB82

Hyatt, Phoenix West

**Health Care II**

Contributed Session

Chair: Najibe Sadatjafarkalaei, Wayne State University,  
4815 Fourth Street, Detroit, MI, 48202, United States

**1 - Modeling the Containment Behavior of Interacting Populations in Response to an Epidemic**

Marzieh Soltanolkottabi, Student, Kansas State University,  
1601 Roof Dr #G25, Manhattan, KS, 66502, United States,  
David Ben-Arieh

Epidemic disease outbreaks are among the major threats to the sustenance and health of human societies. Modeling the dynamics of epidemic disease outbreaks and the corresponding social response to it is one of the techniques that can help public health policy makers make better decisions and devise better policies. The aim of this study is to use spatial games under public goods policies and explore efficient strategies for containment and control of large scale epidemics. The public goods game enables players to choose not to be vaccinated and thus to not contribute to the public common defense.

**2 - Spillover Success in Healthcare Information Technology**

Ankita Srivastava, Graduate Teaching Assistant, Oklahoma State University, Stillwater, OK, 74074, United States,  
Surya B. Ayyalasomayajula, Taha Havakhor

The looming retirement crisis has led US federal government to take immediate measures to fix the exorbitant healthcare system. Since HITECH, there is a significant increase in the adoption & meaningful use of certified EHR's and therefore understanding business value of IT in healthcare is gaining research interest. American Hospital Association annual survey data from 2012 to 2016 is used to test the hypothesis that IT investments of geographically proximal hospital have spillover effects on the revenue of the focal hospital. Our results have implications for both literature and practice.

**3 - Cost-effective Evaluation of Public Health Policies for Cervical Cancer**

Karen Angulo, Universidad de los Andes, Cra 1 N. 18A-12, Bogotá,  
110111, Colombia, Ivan Mura

Predicting the long-term effects of vaccination and screening programs against Cervical Cancer (CC) is not trivial at all, as it builds upon the ability to compound the uncertainties associated with the results of interventions. We propose compartmentalized epidemiological simulation models based on differential equations, which represent population dynamics, HPV transmission, likelihood of infection clearance, virus induced precancerous lesions and eventually appearance of CC. Models are implemented into an open software tool that allows predicting the effects of public health policies for CC prevention and surveillance, providing valuable support to healthcare decision-makers.

**4 - Evaluating Network Based Interventions for Opioid Abuse using Agent Based Modeling**

Lesley Clack, University of Georgia, Athens, GA, United States,  
Aaron Schecter

While there is research available on the efficacy of predicting intervention strategies in a variety of contexts, this type of modeling has not been tested in rural/underserved opioid populations. While many potential interventions for treating substance abuse exist, their efficacy can vary greatly across locations, populations, and types of addictions. The goal of this research study was to explore and rigorously define the spectrum of available intervention strategies for opioid abusers in rural/underserved communities, and evaluate the potential effectiveness of each intervention strategy using statistical tools and relevant empirical evidence.

**5 - Dynamic Task Assignment for Coordination of Inpatient Operations in Hospitals**

Najibe Sadatjafarkalaei, Wayne State University, 4815 Fourth Street, Detroit, MI, 48202, United States, Evrim Dalkiran, Alper E. Murat, Ratna Babu Chinnam

Most hospital systems in the U.S. have employed some form of an Electronic Health Record (EHR) system in recent years to improve health outcomes. While EHR systems form a critical data backbone for improving operational efficiencies, there is a need for platforms that can promote situational awareness, predictive operational intelligence, and eventually coordinated orchestration. We present a real-time resource and task assignment model to coordinate inpatient operations to reduce patient waiting times, focusing on bed assignment, environmental services, and patient transport.

## ■ TB83

Hyatt, Remington

**Practice- Health Care II**

Contributed Session

Chair: Ajit Appari, Worcester Polytechnic Institute, Worcester, MA, 000, United States

**1 - Improving Outpatient Process with Multi Fidelity Models**

Bowen Pang, Tsinghua University, Tsinghua Univ. Zijing 14#,  
Beijing, 100084, China, Xiaolei Xie, Yijie Peng, Bernd Heidergott

Physicians with outpatient departments in large Chinese hospitals face tremendous amount of workload. The limited time spent with each patient contribute to dissatisfaction while it is costly to increase the number of nurses and doctors. We develop a simulation model to analyze the outpatient process in the Department of Ophthalmology in Beijing Tongren Hospital. Using simulation output, we estimate the parameters of the queuing model with tandem MMC queues which balances the system performance and the costs incurred by increased staffing level. The optimal solution obtained by the queuing model is used to find improved settings via simulation model.

**2 - Optimizing a High Volume Surgical Center Through Improved Team Dynamics: An Application of Social Network Modeling in Healthcare Operations**

Scott T. DeNegre, Vice President, Hospital for Special Surgery, 535 East 70th Street, New York, NY, 10021, United States, Nathaniel Hupert, Mayu Sasaki, Jingyan Yang, Justin Do, Abigail Schmucker, David Grace, Meghan Kirksey, Alexander McLawhorn, Stephen Lyman, Steve Magid

Increasing operating room (OR) capacity provides greater access for patients, improves the financial sustainability of health systems, and is a health policy priority here and abroad. Traditional methods for increasing capacity require multiyear, multimillion dollar capital projects; in this paper, we explore methods for increasing OR capacity through improved team dynamics and develop a novel approach to quantifying team consistency using network models. Results from a high volume surgical center are presented, demonstrating that consistent surgical teams deliver improved efficiency and suggesting that OR capacity can be increased by approximately 20% through improved staffing models.

**3 - The Influence of Operational Proximity on Hospitals' Post-acquisition Service-mix Strategies**

Yueqiao Cheng, University of Houston, 4800 Calhoun Rd, Houston, TX, 77004, United States, Xiaosong David Peng, Yuan Ye

The study examines whether acquired hospitals reconfigure their service-mix to become more focused after acquisitions. If so, is the enhanced focus associated with improved post-acquisition performance (i.e., cost and quality), and do more common service lines and a shorter geographic distance between acquired and acquirer hospitals enable an acquired hospital to implement a more focused strategy?

**4 - How Philanthropic are They? The Impacts of Directors' Professional Background on the Performance of Nonprofit Private Hospitals**

Ajit Appari, Worcester Polytechnic Institute, Worcester, MA, United States, Milly Wang

The widening healthcare disparity in the US raises concern on the philanthropic intent of nonprofit private hospitals (NPPHs), and whether they provide charity care to community to satisfy legal threshold or engage in beyond the legal requirements. Building on the Upper Echelon and Corporate Governance literature, we examine whether philanthropic performance of NPPHs vary by professional background of their board of directors; and if this relationship differs by market competition. We report findings from the analysis of 215 NPPHs in California during 2007-2012 using hierarchical linear model.

## ■ TB84

Hyatt, Russell

**Disaster and Disruption Management**

Contributed Session

Chair: Shawn Bhimani, School of Business, University of Leicester, 918 Garrison Ridge Blvd, England, 37922, United Kingdom

**1 - Performance of Alternative Linear Objective Functions in Effectiveness Fairness Trade Off**

Gokalp Erbeyoglu, Bogazici University, Bogazi i Universitesi Endustri, Muhendisligi Bolumu Bebek, Istanbul, Turkey, Umit Bilge

The quality of a humanitarian response plan is judged by two contradicting objectives: timely and fair satisfaction of demand. In this study, we provide alternative objectives that can focus on effectiveness and fairness to distribute relief items in disaster response. In our multi-depot multi-vehicle routing model with split deliveries, tours are open. Also, the demand occurrences are not limited to the initial period. The proposed objective functions capture both the timeliness and satisfaction levels in a way that their progression is important, rather than their final values. The performance is investigated in comparison to various related performance measures in the literature.

**2 - Applying Backup Agreements with Penalty Scheme under Credit Guarantee Mechanism**

Cheng-feng Wu, Hubei University of Economics, No. 8 Yangqiaohu Road Jiang-xia Wuchang, Wuhan, Hubei, 430205, China

This study examines the issue of the strait of capital shortage in SME supplier and supply risks from the buyer's perspective. The buyer builds a credit guarantee mechanism in which a SME supplier is guaranteed to finance the shortfall in capital from the financial institution. This study considers the backup agreement with penalty scheme in which the buyer places the reservation quantity at the backup supplier and pays the penalty for the reservation that has not been ordered. The buyer considers the backup agreement with penalty scheme as its sourcing strategy to manage its supply basis and increase its profits under credit guarantee mechanism.

**3 - A Methodology for Infrastructure Resilience Metric Assessment**

Mohammad Najarian, University of Houston, 4722 Calhoun Road, Engineering Building 2, Houston, TX, 77204-4008, United States, Gino J. Lim

Natural and manmade disasters are unavoidable and they may incur extravagant costs. Resilience enhancement activities, which aim at reducing the disasters' impact, rely on resilience metrics to find areas for improvement and measure the effectiveness of enhancements. Several resilience metrics have been suggested. However, the question is that whether they reveal the characteristics determined by the underlying framework or not. We address this question by defining a valid resilience metric and a novel methodology for assessing the validity. This methodology combines the experimental design methods and statistical analysis techniques that can be utilized to examine the resilience metrics.

**4 - How Supply Chains Break**

Shawn Bhimani, University of Leicester, England, 37922, United Kingdom

We present an enhanced framework of supply chain vulnerability through an analysis of 200 years of supply chain failures. This builds on previous literature in supply chain management, disruptions and risk mitigation. Through our extensive analysis of past failure types and causes, we offer an updated framework to better understand, prevent and predict catastrophic supply chain failures. This is useful for continuity of operations in corporate, military, and humanitarian supply chains, which can save money and lives. It also has implications for supply chain resiliency, robustness and the potential inducement of disruptions.

## Tuesday, 12:05PM - 1:35PM

## ■ TC01

North Bldg 121A

**Data-driven Distributionally Robust Optimization**

Sponsored: Optimization/Optimization Under Uncertainty

Sponsored Session

Chair: Rui Gao, Georgia Institute of Technology, Atlanta, GA, 30332-0205, United States

**1 - Enhancing Statistical Performances in Extreme Event Analysis via Distributionally Robust Optimization**

Xinyu Zhang, Columbia University, NYC, NY, 10025, United States, Henry Lam, Clementine Mottet

One bottleneck in analyzing extreme events is that, by its own definition, tail data is often scarce. Conventional approaches fit data using justified parametric distributions, but the inherent bias-variance tradeoff in the parametric fitting can hinder the estimation reliability. We discuss approaches using distributionally robust optimization as a nonparametric alternative that, through a different conservativeness-variance tradeoff, can mitigate some of the statistical challenges in estimating tails. We discuss the solution approaches and statistical performances compared to the conventional methods.

**2 - Distributionally Robust Expectation using Dominance Information**

Ruiwei Jiang, University of Michigan, 1205 Beal Ave., Ann Arbor, MI, 48109, United States, Yuan Yuan Guo

This talk discusses the expectation of a random function when the distributional information of the uncertain parameters consists of moment (e.g., mean, covariance, support) and probabilistic dominance information. We find that the expectation in this setting can be bounded using conic programming. Finally, we demonstrate the theoretical results via case studies on appointment scheduling.

**3 - Faster Rates of Convergence of Stochastic Gradient Descent for Wasserstein Distributionally Robust Optimization**

Karthik Murthy, Columbia University, Department of IEOR, 500 West 120th Street, New York, NY, 10027, United States, Jose Blanchet, Fan Zhang

Among the various notions of distributionally robust optimization (DRO) schemes being investigated to beat "optimizer's curse" when performing optimization under uncertainty, Wasserstein distance based DRO has gained much attention recently because of its relationship with machine learning algorithms that successfully employ regularization. In this talk, we shall see how these Wasserstein based DRO formulations can be solved almost as fast, and in some cases even faster(!) than, the respective nonrobust schemes for a large class of useful models. Specifically, we establish faster rates of convergence by studying the strong convexity of robust objective functions.

**4 - Distributionally Robust Hypothesis Testing**

Rui Gao, Georgia Institute of Technology, 755 Ferst Drive NW, ISyE Main Building, Atlanta, GA, 30332-0205, United States

We develop an approach to hypothesis testing problems that find the optimal test for deciding an observation belongs to a certain family of distributions. Such family of distributions is a non-parametric data-driven set of hypotheses based on Wasserstein distance. Leveraging tools from distributionally robust optimization and chance-constrained optimization, we provide convex reformulations of such problems which render a nearly optimal test.

## ■ TC02

North Bldg 121B

**Joint Session OPT/Practice Curated: Stochastic Integer Program: Theory and Applications**

Sponsored: Optimization/Optimization Under Uncertainty

Sponsored Session

Chair: Jie Zhang, Virginia Tech, Blacksburg, VA, 24060, United States,

**1 - Stochastic Programming Models for Coordinated and Non-Coordinated Natural Gas and Power Systems**

Dan Hu, Iowa State University, Ames, IA, 50010, United States, Sarah M. Ryan

With the growing proportion of electric power generated from natural gas, greater coordination between the two energy systems is gaining importance. We formulate separate but interacting stochastic programs to model the existing non-coordinated daily operations of the natural gas and electric power systems and a single stochastic program for a coordinated alternative. Variable renewable energy generation and demand for gas other than for electric power generation are the uncertain quantities. Through numerical studies we assess the benefits of coordination in terms of the distribution of the daily operational cost.

**2 - Polyhedral Analysis of the Single-node Fixed-charge Network Flow Problem under Uncertainty**

David Mildebrath, Rice University, Houston, TX, United States, Victor Gonzalez, Mehdi Hemmati, Andrew J. Schaefer

We consider a two-stage extension of the single-node fixed-charge network flow (SNFCNF) problem with uncertain demands and capacities. The stochastic SNFCNF problem is an important problem arising throughout the fields of network design, vehicle routing, and elsewhere. We present the first polyhedral results for the associated polytope, and establish fundamental connections between facets of the single-scenario (i.e. deterministic) SNFCNF polytope and its stochastic extension. Finally, we provide computational examples to quantify the degree to which knowledge of the structure of each single-scenario sub-problem improves the solution to the extensive form of the stochastic problem.

### 3 - Robust Multi-product Newsvendor Model with Substitution under Cardinality-constrained Uncertainty

Jie Zhang, Virginia Tech, 820 Newport Terrace, Blacksburg, VA, 24060, United States, Weijun Xie

This paper studies robust multi-product newsvendor model with product substitutions (RMNMPs). The objective of RMNMPs is to determine the optimal order quantities, which maximize the worst-case total profits against budget uncertainty set of the demand. Although RMNMPs is in general nonconvex and NP-hard, we are able to identify several special cases, where the optimal order quantities can be completely characterized, and interesting managerial insights are drawn. For a general RMNMPs, we develop an efficient cutting plane based solution approach by exploring the submodularity of inner minimization problem. The numerical study demonstrates the effectiveness of the proposed algorithm.

### 4 - A Finite E-convergence Algorithm for Two-stage Convex 0-1 Mixed-integer Nonlinear Stochastic Programs with Mixed-integer First and Second Stage Variables

Can Li, Carnegie Mellon University, Pittsburgh, PA, United States, Ignacio E. Grossmann

We propose a generalized Benders decomposition-based branch and bound algorithm, GBDDBAB, to solve two-stage convex 0-1 mixed-integer nonlinear stochastic programs with mixed-integer variables in both first and second stage decisions. We construct the convex hull of each subproblem by applying basic steps to convert each subproblem from conjunctive normal form (CNF) to disjunctive normal form (DNF). We prove the algorithm has finite  $\epsilon$ -convergence if we branch on the continuous first stage variables. Since constructing the convex hull can be expensive, we propose a sequential convexification scheme that progressively applies basic steps to the CNF.

### 5 - Computational Evaluation of New Dual Bounding Techniques for Sparse PCA

Guanyi Wang, Georgia Institute of Technology, Atlanta, GA, United States, Santanu Subhas Dey, Rahul Mazumder

Principal component analysis (PCA) is one of the most widely used dimensionality reduction method in statistics. For additional interpretability, it is desirable to require cardinality constraint, known as the sparse principal component analysis (SPCA). However, the SPCA problem and its  $\ell_1$  relaxation are hard to compute. We give a framework (convex integer program, IP) that certifies the optimality of solutions of SPCA problem, via dual bounds. We show that, in theoretical, the dual bound obtained from convex IP problem is affinely upper bounded by the optimal value of the SPCA problem, and in practical, plausible dual bounds are obtained via the convex IP method in acceptable time.

## ■ TC03

North Bldg 121C

### Product and Process Innovation in Healthcare and Energy Industries

Sponsored: Technology, Innovation Management & Entrepreneurship

Sponsored Session

Chair: Zhili Tian, Florida International University, Weston, FL, 33327-2444, United States

#### 1 - Capacity Planning with Probabilistic Outcome Ambiguity

Heejung Kim, University of California, Berkeley, Albany, CA, 94706, United States, Philip Kaminsky

We consider a capacity planning model where demand in each period is determined by the outcome of series of binary events, such as clinical trials in pharmaceutical industries. The outcome of these events is often uncertain, and estimating exact probability of outcome is difficult. We develop approaches to solve capacity expansion planning models that are robust to ambiguities in probability of success for different objectives - minimizing expected cost, value at risk and conditional value at risk. We formulate these models as (stochastic) robust integer programs with scenario trees. We develop and test a variety of heuristics for this setting.

#### 2 - Operating Room Scheduling with Sequential Tasks and Defined Wait Intervals

James W. Hamister, Wright State University, Raj Soin College of Business, Dayton, OH, 45435, United States, Michael Magazine, George Polak

We develop an optimization model for scheduling paired tasks subject to intervening procedures in an operating room environment. The durations of the intervening procedures are bounded from below and above. The objective is to minimize overall makespan. The model is tested with empirical data from a tissue bank service.

### 3 - Optimal Investment in Product Development and Marketing Communication in Pharmaceuticals

Zhili Tian, Coastal Carolina University, 1305 Harvester Cir, Myrtle Beach, SC, 33327-2444, United States

Marketing spending on drugs is often close to that for developing a new drug. Only around 20 new drugs are approved every year for the pharmaceutical industry. The low rate of new drug development stems from the financing constraints at many firms because such high investments from both marketing and new drug development. Because of high risk in new drug development, firms have to use internal funding to support their drug development. We develop models to address the investment in the current drugs and development of new drugs where the funding comes from the internal source. Our methods optimally allocate the fund between marketing and new drug development while considering financing constraints.

### 4 - Evaluating Emerging Energy Technology Lifecycles using Mixed Integer Programming

Joshua Pearson, Colorado School of Mines, Golden, CO, 80401, United States

We develop methodologies to evaluate the feasibility of market penetration for new technologies based economic viability. We use as a case study a concentrated solar power device. With an existing piece of engineering software, the System Advisory Model, we examine the financial implications of various industry-standard designs. For each design, we employ a mixed-integer program to determine a cost-minimizing operational strategy for the device under certain market conditions. Finally, we assess long-term economic viability of the device, and draw conclusions about the types of methodologies that can predict the success of investment strategies for emerging technologies.

## ■ TC04

North Bldg 122A

### Integrated Methods and Decomposition Approaches

Sponsored: Optimization/Integer and Discrete Optimization

Sponsored Session

Chair: Joris Kinable, PhD, Eindhoven University of Technology, P.O. Box 513, Eindhoven, 5600 MB, Netherlands

#### 1 - Home Healthcare Integrated Staffing and Scheduling

Louis-Martin Rousseau, Ecole Polytechnique de Montreal, Cp 6079 Succ Centre-Ville, Montreal, QC, H3C 3A7, Canada, Maria Isabel Restrepo Ruiz

Workforce planning for home healthcare represents an important and challenging task involving complex factors associated with labour regulations, caregivers' preferences, and demand uncertainties. Motivated by these challenges, we present a two-stage stochastic programming model for employee staffing and scheduling which relies on Context-free Grammars hyper-graphs. The proposed model is tested on real-world instances, where we evaluate the impact in costs, caregiver utilization, and service level, by using different scheduling policies and recourse actions.

#### 2 - Consistency for Mixed Integer Programming

John Hooker, Carnegie Mellon University, Tepper School of Business, Pittsburgh, PA, 15213, United States, Danial Davarnia

Concepts of consistency have long played a key role in constraint programming but have not arisen in mathematical programming. Consistency is fundamental, because problems that satisfy consistency properties can be solved with less backtracking. We show how a basic type of consistency can be adapted to mixed integer programming (MIP) by taking linear relaxations into account. This novel perspective on MIP helps explain why certain cuts are effective and suggests new techniques for accelerating search.

#### 3 - Optimizing Trip Sharing in Community-based Urban Commuting

Pascal Van Hentenryck, University of Michigan, 1813 IOE Building, 1205 Beal Avenue, Ann Arbor, MI, 48108-2117, United States, Mohd Hafiz Hasan

We describe optimization techniques for optimizing trip sharing in urban commuting. The starting point is the identification of important properties that must be satisfied by any successful trip-sharing platform, which give rise to complex optimization problems. The presentation describes potential solution techniques and evaluates them on a real case study.



#### 4 - A Local Search Framework for Compiling Relaxed Decision Diagrams

Michael Roemer, Martin Luther University, Universitätsring 3,  
Halle, Saale, 06108, Germany, Andre Augusto Cire,  
Louis-Martin Rousseau

We presents a local search framework for compiling relaxed decision diagrams (DDs). It consists of a set of elementary DD manipulation operations including a redirect operation introduced in this paper and a general algorithmic scheme. We show that the framework can be used to reproduce standard DD compilation schemes and to create new compilation strategies. In experiments for the knapsack problem, the multidimensional knapsack problem and the set covering problem we compare different compilation methods. It turns out that a new strategy based on our framework consistently yields better bounds, for limited-width DDs than previously published heuristic strategies.

#### ■ TC05

North Bldg 122B

#### Conic Optimization in Robust Optimization

Sponsored: Optimization/Linear and Conic Optimization

Sponsored Session

Chair: Jonathan Yu-Meng Li, Telfer School of Management,  
University of Ottawa, Ottawa, ON, K1N 6N5, Canada

##### 1 - Robust Quadratic Programming with Mixed-integer Uncertainty

Areesh Mittal, University of Texas at Austin, Austin, TX, 78703,  
United States, Can Gokalp, Grani Adiweni Hanasusanto

We study robust convex quadratic programs where the uncertain problem parameters can contain both continuous and integer components. We show that these problems can be reformulated as copositive programs of polynomial size. These convex optimization problems admit a tractable semidefinite programming approximation. We prove that the popular approximate S-Lemma method, valid only in the case of continuous uncertainty, is weaker than our approximation. We extend the results to the two-stage robust quadratic optimization problem if the problem has complete recourse. We demonstrate the superiority of our proposed method over the state-of-the-art solution schemes on several problem instances.

##### 2 - Solving Robust Counterparts of Risk-Averse Stochastic Optimization Problems as Second-Order Cone Programs

Jonathan Li, Telfer School of Management, University of Ottawa,  
Ottawa, ON, K1N 6N5, Canada

We show how robust solutions can be derived for risk-averse stochastic optimization problems when only the mean-covariance information is available for the uncertain parameters. We prove that for any such problem that employs a coherent risk measure, the robust solution can always be obtained by solving certain second-order cone programs. Moreover, we identify the corresponding worst-case scenario (distribution) in closed-form, which sheds light on the connection between one's risk aversion attitude and the worst-case distribution.

##### 3 - Risk-averse Two-stage Stochastic Convex Optimization with First-stage Mixed Integer Problem

Ricardo A. Collado, Stevens Institute of Technology, 36 Gates Ave.,  
Gillette, NJ, 007933, United States, Somayeh Moazeni

We formulate a risk-averse two-stage stochastic optimization problem and present solution strategies based on methods such as L-shape and the cutting-plane method. We extend our formulation to a general two-stage risk-averse convex stochastic optimization problem and discuss regularized cutting-plane methods for solution and approximation. Next we extend our results to the case where the first-stage variables are mixed integer but the recourse variables are continuous. Finally, we present results obtained from applying our methods to a problem on resource allocation for contingency planning.

##### 4 - Preference Elicitation and Robust Optimization with Multi-attribute Quasi-concave Choice Functions

Wenjie Huang, National University of Singapore, Singapore,  
William Haskell, Huifu Xu

In this paper, we consider ambiguity in choice functions over a multi-attribute prospect space. Our main result is a robust preference model where the optimal decision is based on the worst-case choice function from an ambiguity set constructed through preference elicitation with pairwise comparisons of prospects. Differing from existing works in the area, our focus is on quasi-concave choice functions which enables us to cover a wide range of utility/risk preference problems. We propose two approaches based respectively on the support functions and level functions of quasi-concave functions to develop tractable formulations of the maximin preference robust optimization model.

#### ■ TC06

North Bldg 122C

#### Joint Session OPT/Practice Curated: MINLP Theories and Applications

Sponsored: Optimization/Global Optimization

Sponsored Session

Chair: Asteroide Santana, ISyE, Georgia Tech, Atlanta, GA,  
United States

##### 1 - A Minor Perspective on Rank Constrained Optimization

Shixuan Zhang, Georgia Institute of Technology, Atlanta, GA,  
United States, Andy Sun

Many combinatorial and mixed-integer nonlinear optimization problems can be formulated with constraints on matrix ranks. We propose a new perspective on dealing with rank constraints by reformulations using matrix minors. We investigate the implications of this minor perspective on generating convexification hierarchy and strong valid inequalities for the cut polytope and some QCQPs in complex variables such as AC optimal power flow.

##### 2 - Preprocessing Algorithms and Tightening Constraints for Multiperiod Blend Scheduling Problem

Yifu Chen, University of Wisconsin-Madison, Madison, WI,  
United States, Christos T. Maravelias

The multiperiod blend scheduling problem (MBSP) considers the scheduling in a production environment that includes blending processes. MBSP can be considered as a scheduling extension of the pooling problem. In this work, we first introduce novel preprocessing algorithms to calculate bounds on critical variables in MBSP. The bounds obtained from the preprocessing algorithms, along with the new variables we defined to address the product specific features in MSBP, are used to generate tightening constraints. The methods are applicable to previously proposed MINLP models for MBSP, as well as MILP models obtained using different linear relaxation/approximation methods.

##### 3 - A Compact Linear Programming Formulation of the Steiner Tree Problem for a Fixed Number of Terminals

Matias Siebert, Georgia Institute of Technology, Atlanta, GA,  
United States, Shabbir Ahmed, George L. Nemhauser

Given an undirected graph  $G=(V,E)$  with non-negative edge weights, and a subset  $R$  of the vertices  $V$ , the Steiner tree problem seeks to find the minimum weighted tree  $T$  that connects all vertices in  $R$ . This problem can be equivalently stated as selecting an arbitrary node  $r$  in  $R$ , and finding the minimum weighted arborescence rooted in  $r$ , whose leaves correspond to nodes in  $R \setminus \{r\}$ , in the directed version of graph  $G$ . We observe that in any of those  $r$ -arborescences, the paths connecting  $r$  to the nodes in  $R \setminus \{r\}$  form a Laminar family. This fact leads to a new linear programming formulation of polynomial size for fixed  $|R|$ , whose extreme points are integer and whose optimal solution is an optimal Steiner tree.

##### 4 - New SOCP Relaxation and Branching Rules for Bipartite Bilinear Programs

Asteroide Santana, Georgia Tech, Atlanta, GA, 30318,  
United States

The bipartite bilinear program (BBP) is a QCQP where the variables can be partitioned into two sets such that fixing the variables in any one of the sets results in a linear program. We propose a new second order cone representable (SOCP) relaxation for BBP, which we show is stronger than the standard SDP relaxation intersected with the boolean quadratic polytope. We then propose a new branching rule inspired by the construction of the SOCP relaxation and show that our approach outperforms the commercial solver BARON in obtaining dual bounds for instances of a new application of BBP.

## ■ TC07

North Bldg 123

**Joint Session OPT/Practice Curated: Network Optimization Models and Applications**

Sponsored: Optimization/Network Optimization

Sponsored Session

Chair: Larry J. LeBlanc, Vanderbilt University, Owen Graduate School of Mgmt, Nashville, TN, 37203, United States

**1 - Fireline Construction in a Heterogeneous Forest Landscape**

Xu Yang, Northeastern University, 360 Huntington Avenue,  
Snell Engineering, Boston, MA, 02115, United States,  
Emanuel Melachrinoudis

Most often wildfires are contained with a construction of fireline around the fire perimeter by clearing of combustible material or sufficiently wetting to prevent fire spread. Existing models in the literature assume homogeneous fire environment. This paper presents a novel way of generating an optimal fireline construction through heterogeneous landscape using a network approach. Voronoi Polygons are utilized to represent the homogeneous areas. Dijkstra's algorithm is used to find the fastest paths at a safe distance for two crews who work simultaneously in opposite directions to encircle and contain the fire.

**2 - Locomotive Assignment Problem: Integrating the Strategic, Tactical and Operational Level Aspects**

Prashant Premkumar, Doctoral Student, Indian Institute of  
Management Kozhikode, IIM Kozhikode P.O., Kozhikode, 673570,  
India, Ram Kumar P. N

Over the past couple of centuries, with the increase in the significance of the railways to the economy, the complexity of the railway network and consequently the decision making involved has only increased. Among the host of problems in railways management, we attempt to integrate the strategic, tactical and operational level aspects of one of the most important problems, which is the Locomotive Assignment Problem (LAP). We also demonstrate that by innovatively modelling the problem through the addition of a valid equality, the lower bounds can be improved substantially, thereby reducing the solution time.

**3 - Blood Bank Mergers from a Supply Chain Perspective: A Case Study**

Amir H. Masoumi, Assistant Professor of Management, Manhattan  
College, O'Malley School of Business, Riverdale, NY, 10471,  
United States, Jan Hoffmann, Min Yu

We utilize a supply chain network model to analyze a recent case of merger between two blood banks in California. Our methodological framework evaluates the synergy associated with the merger from a total cost perspective. The proposed model takes into account the operational cost, discarding cost of waste, as well as the potential capacity coverage penalty throughout the blood supply chain. For the case study, clustered blood collection zones are considered in addition to aggregated demand regions representing the hospitals served by the two blood banks. Solution to the proposed models yields the optimal link flows and the link capacity coverages corresponding to the pre- and post-merger problems.

**4 - Societal Networks in Smart City**

Rupe Xu, The University of Texas at Dallas, Richardson, TX,  
75081, United States, Andras Farago

In the modern city, societal networks, such as transportation network, communication network, gas pipeline network, delivery network etc., play an important role for the convenience of citizens. Adopting artificial intelligence and Internet of Things (IoT) to societal networks would lead to better technological services. These networks, however, are usually of extremely large scale and vary frequently, thus bringing a lot of new computational challenges. In this research, we apply new computation techniques to handle computational challenges for societal networks in the smart city, providing efficient and practical solutions.

**5 - Using Spreadsheet Maps for Heuristic Site-selection Algorithms**

Larry J. LeBlanc, Vanderbilt University, Owen Graduate School of  
Mgmt, Nashville, TN, 37203, United States, Michael Bartolacci,  
Thomas A. Grossman

Because of the well-known difficulty of finding exact solutions to large scale 0-1 location models, heuristic algorithms are often used. We show how to use 3D maps in Excel and Tableau to guide the selection of sites to open in a global setting from a large set of potential sites. Formulas for a different customer service radius for each site are given. Possible heuristics are discussed.

## ■ TC08

North Bldg 124A

**Primal-Dual Methods for Stochastic Optimization**

Sponsored: Optimization/Nonlinear Programming

Sponsored Session

Chair: Qihang Lin, The University of Iowa, Iowa City, IA, 52245, United States

**1 - Structured Nonconvex Optimization Models: Algorithms and Iteration Complexity Analysis**

Tianyi Lin, University of California, Berkeley, 407, Cornell Avenue,  
Unit 11, Albany, CA, 94706, United States, Bo Jiang, Shiqian Ma,  
Shuzhong Zhang

Nonconvex and nonsmooth optimization problems are encountered in statistics, business and engineering, but are not widely recognized as a technology in the sense of scalability. This paper aims to take one step in this direction. Indeed, we consider some constrained nonconvex models in block variables with coupled affine constraints, and introduce the  $\epsilon$ -stationarity conditions. We develop two proximal-type variants of the ADMM, assuming the proximal updates can be implemented for all the block variables except for the last block, for which either a gradient step or a majorization-minimization step is implemented. We also establish an iteration complexity bound of  $\mathcal{O}(1/\epsilon^2)$ .

**2 - Randomized Primal-Dual Algorithms for Semi-Infinite Programming**

William Haskell, National University of Singapore, Singapore,  
Singapore

This paper presents a novel algorithm for semi-infinite programming which combines random constraint sampling with the classical primal-dual method. We show that this algorithm achieves an  $\mathcal{O}(1/T^{1/2})$  and  $\mathcal{O}(1/T^{1/4})$  rate of convergence for bounds in probability, in terms of the optimality gap and constraint violation, respectively, where  $T$  is the number of iterations.

**3 - Iteration Complexity of Collaborative Subgradient Method under Error Bound Condition and Weak Convexity**

Runchao Ma, The University of Iowa, 21 E. Market St, S380,  
Pappajohn Business Building, Iowa City, IA, 52242, United States,  
Qihang Lin

Collaborative subgradient descent (CSGD) method is a generic optimization algorithm for general nonlinear constrained continuous optimization. In this work, we consider using the CSGD method for two important classes of non-smooth constrained optimization problems: (1) convex problem satisfying error bound conditions; (2) non-convex problem with weak convexity. We analyze the iteration complexity of the CSGD method for finding an  $\epsilon$ -optimal or  $\epsilon$ -stationary point under each scenario, respectively.

**4 - Scalable Bilinear  $\pi$  Learning using State and Action Features**

Yichen Chen, Princeton University, Princeton, NJ, 08540,  
United States, Lihong Li, Mengdi Wang

In this work, we develop a scalable, model-free algorithm called bilinear  $\pi$  learning for reinforcement learning when a sampling oracle is provided. The algorithm has several advantages. First, it adopts (bi)linear models to represent the high-dimensional value function and state-action distributions, using state and action features. Its run-time complexity depends on the number of features, not the size of the underlying MDPs. Second, it operates in a fully online fashion without having to store any sample, thus having minimal memory footprint. Third, we prove that it is sample-efficient, solving for the optimal policy with a sample complexity linear in the dimension of the parameter space.

## ■ TC09

North Bldg 124B

**Nonlinear and Stochastic Optimization**

Sponsored: Optimization/Nonlinear Programming

Sponsored Session

Chair: Raghu Bollapragada, Northwestern University, Evanston, IL, 60201, United States

**1 - Randomness and Permutations in Coordinate Descent**

Mert Gurbuzbalaban, Rutgers, New Brunswick, NJ, United States

We consider coordinate descent (CD) methods with exact line search on convex quadratic problems. Our main focus is to study the performance of the CD method that use random permutations in each epoch and compare it to the performance of the CD methods that use deterministic orders and random sampling with replacement. We focus on a class of convex quadratic problems with a diagonally dominant Hessian matrix, for which we show that using random permutations instead of random with-replacement sampling improves the performance of the CD method in the worst-case. This is joint work with Asu Ozdaglar, Nuri Denizcan Vanli and Stephen Wright.

**2 - A Progressive Batching L-BFGS Method for Machine Learning**

Raghu Bollapragada, Northwestern University, 2145 Sheridan Road, Evanston, IL, 60201, United States, Jorge Nocedal, Hao-Jun M. Shi, Dheevatsa Mudigere, Ping T. Peter-Tang

We present a new version of the L-BFGS algorithm for machine learning that combines three basic components - progressive batching, a stochastic line search, and stable quasi-Newton updating. The motivation for this approach is to combine the early efficiency and good generalization properties of the SGD method and the fast convergence, stability and parallelization opportunities offered by large batches. We illustrate the performance of the method on logistic regression and deep neural network models.

**3 - Inexact Non-convex Newton-type Methods**

Fred Roosta, University of Queensland, Brisbane, Australia

For solving large-scale non-convex problems, we propose inexact variants of trust region and adaptive cubic regularization methods, which incorporate various approximations. In particular, in addition to inexact sub-problem solves, both the Hessian and the gradient are suitably approximated. Using mild conditions on such approximations, we show that our proposed inexact methods achieve similar optimal worst-case iteration complexities as the exact counterparts. Our proposed algorithms do not require knowledge of any unknowable problem-related quantities and are implementable in practice. We also examine the empirical performance of our algorithms on some real datasets.

**4 - Random Projections for Faster Non-convex Optimization**

Mert Pilanci, Stanford University, Stanford, CA, United States

Randomized dimension reduction has recently become a powerful tool in machine learning. We consider random projection methods in the context of non-convex optimization problems. First, we introduce a statistical model where the maximum likelihood estimator reduces to fitting a single layer neural network. We show that a second order optimization method with a suitable initialization recovers the global optimum under certain assumptions on the data. We then introduce random projection and sampling strategies that enables faster convergence in terms of clock time. Our results suggest that the proposed method can outperform existing stochastic methods in large scale non-convex optimization.

## ■ TC10

North Bldg 125A

**OM in Semiconductor Manufacturing I**

Sponsored: Manufacturing &amp; Service Oper Mgmt

Sponsored Session

Chair: John W Fowler, Arizona State University, Arizona State University, Tempe, AZ, 85287-4706, United States

Chair: Lars Moench, University of Hagen, University of Hagen, Hagen, 58097, Germany

**1 - Factory Logistics: Material Handling Performance in a Semiconductor Fab**

Gwangjae Yu, Arizona State University, AZ, United States, John W. Fowler

We study a facility layout problem of a semiconductor manufacturing system (SMS). The objective function in facility layout problems usually is to minimize the material flow distance. However, there is a question if this is still valid for an SMS, which is characterized by re-entrant flow and heavy traffic. As a consequence, an SMS often suffers significant traffic congestion throughout the

material handling system. In our study, we simulate different facility layout scenarios to empirically derive a multi-objective function to capture the traffic issue in addition to the distance. Finally, we test the performance of the new objective function by comparing with previous results.

**2 - Algorithms for Short-term Demand Supply Matching in Semiconductor Supply Chains**

Lars Moench, University of Hagen, Enterprise-wide Software Systems, Universitaetsstrasse 1, TGZ, Hagen, 58097, Germany, Raphael Herding, Thomas Ponsignon, Alexander Seitz, Hans Ehm

We propose algorithms for short-term demand supply matching in semiconductor supply chains. The algorithms can be used to simultaneously re-promise orders in demand fulfillment processes. The resulting mixed integer programming formulations are solved using time-based decomposition approaches. The algorithms are assessed in a rolling horizon setting including master planning and order promising activities. We compare the obtained results with results for a rule-based order repromising algorithm. The results demonstrate that the novel short-term demand supply matching algorithms outperform the rule-based approaches.

**3 - A Review of Product Ramping Models in Semiconductor Manufacturing**

Atchuta B. Manda, Doctoral Student, North Carolina State University, Campus Box 7906, Raleigh, NC, 27695-7906, United States, Reha Uzsoy

We review the state of the art in modelling the ramping up of new products in semiconductor wafer fabrication facilities. We present a taxonomy of different problem formulations, learning models, capacity models and related yield and process learning, and suggest directions for future research.

**4 - Intel Minifab and Observations on Operational Control**

Leon McGinnis, Georgia Institute of Technology, Atlanta, GA, 30332-0205, United States

This famous but aging case study comes to life again to demonstrate some fundamental truths—that our analysis models must clearly distinguish plant and control (which they don't today), that operational control is implemented through material handling, and that there is no such thing as a “queue” in the factory. If we simulate queues, we are not simulating the factory, and thus cannot evaluate implementable operational control (scheduling) policies.

## ■ TC11

North Bldg 125B

**Stochastic Inventory Control: Asymptotics and Approximations**

Sponsored: Manufacturing &amp; Service Oper Mgmt

Sponsored Session

Chair: Linwei Xin, University of Chicago, Chicago, IL, 60637, United States

**1 - Exploiting Random Lead Times in Inventory Systems**

Alexander Stolyar, University of Illinois at Urbana-Champaign, 1308 W. Main Street, 156CSL, Urbana, IL, 61801, United States, Qiong Wang

We study the classical single-item inventory system with random replenishment lead times and order crossovers, and propose a new policy that exploits the lead time randomness. Instead of focusing on the inventory position, our policy uses the net inventory level to set a dynamic target for inventory in-transit, and places orders to follow that target. The policy provides a potentially infinite inventory cost reduction compared with the classical Constant Base Stock (CBS) policy. In the case of exponentially distributed lead times, we prove that, as the demand rate becomes large, the expected (absolute) inventory level under our policy vanishes relatively to that under CBS policy.

**2 - LP-based Order-up-To Control for Stochastic Inventory Systems with Sequential Probabilistic Service Level Constraints**

Linwei Xin, University of Chicago, 5807 S. Woodlawn Avenue, Chicago, IL, 60637, United States, Lai Wei, Stefanus Jasim

We consider a stochastic inventory model with non-stationary demands, positive lead time, and sequential probabilistic service level constraints. This is a notoriously difficult problem to solve and, to date, not much progress has been made in understanding the structure of its optimal control, especially for the lost-sales inventory system. In this paper, we propose a simple order-up-to control, whose parameters can be calculated using the optimal solution of a deterministic approximation of the backorder inventory system, and show that it is asymptotically optimal for both the backorder and lost-sales systems in the regime of high service level requirement.



**3 - A Primal-dual Approach to Analyzing Assemble-to-Order Systems**

Levi DeValve, Duke University, 716 Turmeric Lane, Durham, NC, 27713, United States, Sasa Pekec, Yehua Wei

Assemble-to-order (ATO) problems with general structure and integrality constraints are well known to be difficult to solve. We provide new approximation guarantees by approaching the ATO problem from a primal-dual perspective. We design an LP rounding algorithm for the one-period problem that achieves both asymptotic optimality as demand grows large, and a constant factor approximation of 1.8 for any problem instance. We apply our LP rounding analysis to design an asymptotically optimal integral policy in a related dynamic model.

**4 - On the Performance of Tailored Base-surge Policies: Theory and Application at Walmart.com**

Linwei Xin, University of Chicago, 5807 S. Woodlawn Avenue, Chicago, IL, 60637, United States, Long He, Jagtej S. Bewli, John Bowman, Huijun Feng, Zhiwei Qin

We consider the following dual-sourcing inventory problem: one supplier is reliable but has a longer lead time; the other one is not always reliable but has a shorter lead time. It is motivated by a real-world problem at Walmart.com and the lead time differences of many import items could be as large as 12 weeks. We prove that a Tailored-Base Surge (TBS) policy is asymptotically optimal as the lead time difference grows. We also test the performance of TBS by using data from Walmart.com. Our result shows that Tailored-Base Surge outperforms other heuristics.

**TC12**

North Bldg 126A

**Data Driven Research on the Interface Between OM and Marketing**

Sponsored: Manufacturing & Service Oper Mgmt

Sponsored Session

Chair: Xuying Zhao, University of Notre Dame, Notre Dame, IN, 46556, United States

**1 - A Reinforcement Learning Approach for Hotel Revenue Management**

Jun Zhang, Fudan University, School of Management, Fudan University, Shanghai, 200433, China, Ji Chen, Yifan Xu, Peiwen Yu

We develop a data-driven approach for hotel revenue management. In this approach, the dynamic capacity allocation problem for multiple class customers is solved in two steps: First, a recommended average price is computed, and then the capacity allocation decision is made based on the average price. The recommended average price is computed with a reinforcement learning algorithm. The capacity allocation decision is made based on a linear programming model taking into account a hotel's preference for different classes of customers.

**2 - Can Leanness Predict Financial Distress?**

Feng Mai, Stevens Institute of Technology, 1 Castle Point Terrace, Hoboken, NJ, United States, Nagihan Comez-Dolgan, Xuying Zhao

We investigate whether operational slack can predict financial distress. We use quarterly panel data of US manufacturing firms for the period from 1980-2016. Using Merton's distance to default model, we identify a sample of financial distress firm. We then apply LASSO regression to assess the relative importance of operational slack variables as predictors for financial distress. Our results show that operational slack can complement financial ratios commonly used in the existing credit risk literature.

**3 - Product Quality, Consumer Returns, and the Moderating Role of Salesperson**

Xiaojing Dong, Santa Clara University, Marketing Department, Lucas Hall, Santa Clara, CA, 95053, United States, Necati Ertekin

The literature has rigorously explored the relationship between product quality and consumer returns through analytical frameworks under the assumption that improving quality reduces consumer returns. We empirically (1) investigate this relationship with respect to two product quality dimensions, namely objective quality and perceived quality, that have been the focus of operations management and marketing, respectively, and (2) examine the moderating role of salesperson.

**4 - Data-Driven Pricing and Assortment Decisions for Soybean Seeds**

Durai Sundaramoorthi, Washington University in Saint Louis, 10352 Conway Road, Saint Louis, MO, 63131, United States, Lingxiu Dong, Iva Petrova Rashkova

Offering vertical and horizontal assortments is a common and a strategic practice of firms to expand their share of the market. We introduce a hierarchical-ensemble of machine learning and optimization for product assortment in the agricultural context. We optimize the assortment of soybean varieties to grow in the mid-west of the USA. The hierarchical-ensemble framework created in this research paves way to optimize the assortment of seeds of other crops like corn, rice, and wheat. We present the data utilized, the data-driven methodology utilized, and results obtained in our presentation.

**TC13**

North Bldg 126B

**Topics in Learning**

Sponsored: Revenue Management & Pricing

Sponsored Session

Chair: Mohamed Mostagir, University of Michigan, Ann Arbor, MI

**1 - Bayesian Social Learning with Heterogeneous Preferences: Effects of Diversity**

Ali Makhdoumi, MIT, 77 Massachusetts Ave. 32D-640, Cambridge, MA, 02139, United States

Two opposite forces are present in social learning with heterogeneity. First, heterogeneity will make social learning more difficult as the actions of others become less informative. Second, each individual uses more of her information in making decisions and "herds" become less likely. In this talk, we study the interplay between these two forces and characterize the effect of heterogeneity on social learning and its speed.

**2 - Information and Learning in Contests: An Experimental Study**

Mohamed Mostagir, University of Michigan, 701 Tappan Ave, Ann Arbor, MI, 48109, United States, Yan Chen, Iman Yekkehzaare

Contests are a common mechanism for extracting effort from participants. Their use is widespread in a variety of settings like workplace promotions or crowdsourcing. One of the pivotal aspects of contest design is the contest's information structure: what information should the contest designer provide to participants and when should this information be revealed? The answers to these questions have important implications to how players behave and the overall outcome of the contest. We show how the behavior of players significantly deviates from theory predictions and provide recommendations for how these information mechanisms should be designed in light of these experimental findings.

**3 - Impatience and Learning In Services**

Senthil Veeraraghavan, University of Pennsylvania, Wharton School OPIM Department, 545 3730 Walnut Street, Philadelphia, PA, 19104, United States, Hanqin Zhang, Xiao Li

Customers often abandon waiting in queues when they get impatient. Prior literature on Markovian queues shows that it is not rational to quit "midway": it is rational for customers to quit either immediately on arrival (balk) or wait till the completion of their service. We show how abandonment behavior may occur when customers wait and learn in Markovian queues. We model the learning and abandonment behavior of customer who arrives to a system without full knowledge about the service rate but learns more about service rate. Our work reveals interesting features in waiting behavior, showing that customers can be (rationally) more patient in slower shorter queues, than in faster longer queues.

**4 - Technology Adoption and Information Acquisition in a Partnership**

Sasa Pekec, Duke University, Durham, NC, United States

We study technology adoption decisions under uncertainty in a partnership. This requires coordination among partners with non-identical objectives. We show that classical results for a single decision-maker (SDM policy) do not extend to and do not provide guidance for optimal decision-making in a partnership. We also show that it could be optimal for the partnership to prematurely adopt/reject the technology as compared to the SDM policy, and that anticipating premature decisions in a later period could trigger unraveling which leads to a series of premature decisions in earlier periods.

## ■ TC14

North Bldg 126C

**Optimization, Analysis, and Modeling of Service Systems**

Sponsored: Manufacturing &amp; Service Oper Mgmt/Service Operations

Sponsored Session

Chair: David Goldberg, Cornell University, Ithaca, NY, 14850, United States

**1 - On the Design of Service Systems when Servers are Strategic**

Ragavendran Gopalakrishnan, Postdoctoral Associate, Cornell University, Ithaca, NY, United States

We study the impact of strategic server behavior on the optimal design of a service system, which involves the choice of system configuration (pooled with one central queue or dedicated with multiple parallel queues), the routing policy (e.g., Random routing or Fastest Server First), and the staffing policy (how many servers to hire). In this talk, we present key results from jointly optimizing the routing policy (over a large class of rate-based routing policies) and the system configuration (pooled vs. dedicated) at equilibrium and discuss implications for optimizing the staffing policy. We also identify an interesting trade-off between the system performance and server utility at equilibrium.

**2 - Asymptotic Optimality and Heuristics of Base-stock Policies for Perishable Inventory Systems**

Jinzhi Bu, The Chinese University of Hong Kong, Hong Kong NT, Shatin, Shatin, Hong Kong, Xiting Gong, Xiuli Chao

In this paper, we study the asymptotic properties of the performance of the base-stock policies for a classical perishable inventory system with fixed lifetime. We prove that the best base-stock policy is asymptotically optimal with large product lifetime, large demand size, and large unit penalty cost. Moreover, the optimality gap of the best base-stock policy decays exponentially fast to zero in the lifetime and demand size. We also construct a class of simple heuristic base-stock policies with the same asymptotic properties as the best base-stock policy. Finally, we conduct a numerical study to show the effectiveness of the best and heuristic base-stock policies.

**3 - Dual Sourcing and Smoothing under Non-stationary Demand Time Series: Re-shoring with Speedfactories**

Jan A. Van Mieghem, Professor, Northwestern University, Evanston, IL, United States, Robert Boute, Stephen Disney

We investigate the emerging trend of near-shoring a small part of the global production back to local SpeedFactories. The short lead time of the responsive SpeedFactory reduces the risk of making large volumes in advance, yet it does not involve a complete re-shoring of demand. Using a breakeven analysis we investigate the lead time, demand, and cost characteristics that make dual sourcing with a SpeedFactory desirable compared to off-shoring to a single supplier. We extend the celebrated order-up-to replenishment policy to settings where capacity costs exist and demonstrate their excellent performance. We highlight the significant impact of autocorrelated and non-stationary demand series

**4 - Queue Joining Decisions when there is a Prerequisite Condition for Receiving Service**

Tim Huh, University of British Columbia, Vancouver, BC, Canada, Mona Imanpoor Yourdshahy, Steven Shechter

We consider an M/M/1 queueing system in which a customer requires some prerequisite conditions to be met prior to receiving service. We investigate whether an individual arriving to this system should join the queue at that time, wait to join at some future time, or leave the system. We formulate the problem as a Markov decision process and show how the structure of the optimal policy depends on in-queue and out-of-queue waiting costs, the arrival and service rates, as well as the time until the prerequisite condition is satisfied. We present the structural results of an individual's optimal policy.

**5 - New Product Diffusion in Closed-loop Supply Chains**

Emre Nadar, Bilkent University, Department of Industrial Engineering, Bilkent University, Ankara, 06800, Turkey, Baris Emre Kaya, Kemal Guler

We study the sales planning problem of a manufacturer who sells new and remanufactured versions of a product over a finite life cycle. We develop a dynamic model in which demand arrives according to a slightly modified Bass diffusion process and end-of-use product returns required for remanufacturing are constrained by the earlier sales. We show the optimality of partial demand fulfillment in certain time periods when innovators significantly contribute to the diffusion process or an unmet demand is likely to be backlogged to be satisfied with a remanufactured product. Our findings suggest that curbing the initial sales may be desirable for remanufacturable products in fast-clockspeed industries.

## ■ TC15

North Bldg 127A

**Theory and Practice of Revenue Management**

Sponsored: Manufacturing &amp; Service Oper Mgmt/Service Operations

Sponsored Session

Chair: He Wang, Georgia Institute of Technology, Atlanta, GA, United States

**1 - Dynamic Pricing for Parking**

Maokai Lin, Smarking Inc., San Francisco, CA, United States, Yingxiang Yang

Parking is an industry with 30 billion dollar annual revenue in the US, and more than 100 billion dollar worldwide. With the popularization of smartphones, more and more people search and reserve parking spaces online, leading to great opportunities for dynamic pricing and revenue management. At Smarking, we work with our industry partners to dynamically change prices online in real-time for multiple parking locations in Boston and Chicago. In this talk, we will introduce patterns in real-world parking data, approaches we use for dynamic pricing, and results we achieve.

**2 - A Re-solving Heuristic with Uniformly Bounded Loss for Network Revenue Management**

Pornpawee Bumpensanti, Georgia Institute of Technology, 755 Ferst Drive NW, Atlanta, GA, 30332, United States, He Wang

We consider a network revenue management problem. The goal is to find a customer admission policy that maximizes expected revenue over a fixed finite horizon. We study a class of re-solving heuristics. These heuristics periodically re-solve the deterministic linear program (DLP), where random customer arrivals are replaced by their expectations. We find that frequently re-solving the DLP produces the same order of revenue loss as one would get without re-solving. However, by re-solving the DLP at a few selected time points and applying thresholds to the customer acceptance probabilities, we design a new algorithm that has a revenue loss bounded by a constant that is independent of the horizon length.

**3 - Assortment Optimization for Parallel Flights under a Multinomial Logit Choice Model with Cheapest Fare Spikes**

Yufeng Cao, Georgia Institute of Technology, Atlanta, GA, United States, Anton J. Kleywegt, He Wang

The classical multinomial logit (MNL) choice model does not capture the phenomenon that airline customers tend to choose the cheapest fare classes. We study an assortment optimization problem for parallel flights under an extended spiked-MNL model, which introduces a separate attractiveness parameter for the cheapest available fare class on each flight. We show that the corresponding optimal assortment policy selects revenue-ordered assortments. We also propose static booking limit heuristics based on deterministic approximations of the problem. We evaluate different assortment policies in numerical experiments using both synthetic and real-world data provided by an airline partner.

**4 - Online Ad Allocation with Temporally Asymmetric Learning**

Hanzhang Qin, Massachusetts Institute of Technology, 100 Memorial Drive, 8-10 A, Cambridge, MA, 02142, United States, David Simchi-Levi, Xinshang Wang, Yang Sen, Shenghuo Zhu

We study an online resource allocation problem in which heterogeneous customers arrive at time-varying rates. Customer purchase probabilities are unknown and need to be learned in an online fashion. We devise online algorithms that reserve resources for future customers when (i) the total arrival rate of each customer type is known but (ii) the purchase probabilities of different customer types are learned at time-varying speeds due to non-stationary arrivals. We prove performance guarantees for the proposed algorithms. We test the algorithms using huge industrial datasets.

## ■ TC16

North Bldg 127B

### Sustainable and Socially Responsible Operations

Sponsored: Manufacturing & Service Oper Mgmt/Sustainable Operations

Sponsored Session

Chair: Can Zhang, Georgia Institute of Technology, Atlanta, GA, 30309, United States

#### 1 - Designing Platforms for the First Mile

Joann de Zegher, MIT Sloan, Cambridge, MA, 02142, United States, Sergio Camelo, Dan Andrei Iancu, Daniela Saban

Smallholder farmers in developing and emerging economies supply over 50% of global calories. This first mile of global supply chains typically operates inefficiently, is non-traceable, and is difficult to study because smallholder farmers sell through informal networks. We first share how we quantify inefficiencies in such informal first-mile supply chains of Indonesia by integrating large-scale field work and optimization. We then provide an overview of how platforms can alleviate such inefficiencies, and create traceability as a by-product. Finally, we propose a framed field experiment to estimate how much value a proposed platform can create in such resource-constrained environments.

#### 2 - Dynamic Volunteer Staffing in Multicrop Gleaning Operations

Erkut Sonmez, University of Nebraska Lincoln, 730 N. 14th Street, College of Business, University of Nebraska, Lincoln, NE, 68588, United States, Baris Ata, Deishin Lee

Gleaning programs organize volunteer gleaners to harvest leftover crops that are donated by farmers for the purpose of feeding food-insecure individuals and reducing food waste. We develop a dynamic volunteer staffing policy that maximizes the long run average volume of food gleaned.

#### 3 - Tracing Quality to its Source: Quality and Compliance Issues in Distributed Supply Chains

Philippe Blaettchen, INSEAD, Fontainebleau, France, Andre Du Pin Calmon, Sameer Hasija

Modern technologies like blockchain enable unprecedented levels of visibility into multi-tiered supply chains. We investigate the effect of traceability on supply chain quality, compliance, and efficiency for different supply chain structures. We also analyse the optimal deployment strategy of a traceability system, and we model the decision of adopting a traceability technology as a game between the members of a supply chain. While we are motivated by food supply chains, which have traditionally been fraught with waste as well as difficulties in effectively certifying origins and processes, our results are applicable in a general context.

#### 4 - Consistent Allocation of Emission Responsibility in Energy Supply Chains

Sanjith Gopalakrishnan, University of British Columbia, 2053 Main Mall, Vancouver, BC, V6T1Z2, Canada, Daniel Granot, Frieda Granot

Canada's federal government, since 2016, factors in upstream emissions during the environmental impact assessment of energy projects. Motivated by the regulation, we adopt a cooperative game model and propose the nucleolus as a mechanism to apportion upstream emissions. It avoids the distortionary effects of double counting and exhibits a consistency property that is significant in a context wherein energy supply chains span multiple legal jurisdictions. We develop a polynomial-time algorithm and further, derive it as the unique subgame perfect equilibrium to a non-cooperative game induced by two easily stated and verifiable policies, thereby lending a self-implementing policy framework.

## ■ TC17

North Bldg 127C

### Sourcing and Innovation

Sponsored: Manufacturing & Service Oper Mgmt/Supply Chain Sponsored Session

Chair: Cuihong Li, University of Connecticut, Storrs, CT, 06269, United States

Co-Chair: Leon Zhu, University of Southern California, Los Angeles, CA, 90089, United States

#### 1 - The Role of Problem Specifications in Crowdsourced Innovation Contests: Theoretical Analysis and Data Evidence

Zoey Jiang, Stephen M. Ross School of Business, University of Michigan, Ann Arbor, MI, 48104, United States, Yan Huang, Damian Beil

We investigate the role of seekers' problem specifications in crowdsourcing contests to solve design problems. We propose and empirically test a theoretical model featuring different types of information in problem specifications

(conceptual goals, execution guidelines), and the corresponding designer decisions. We solve the model for seekers' optimal decisions: While more execution guidelines always benefit the seeker, more conceptual goals do not. Finally, we discuss a quasi-natural experiment, providing further empirical evidence for our predictions and recommendations.

#### 2 - Sourcing Complex Innovation: Integrated System or Individual Components?

Zhi Chen, INSEAD, 1 Ayer Rajah Avenue, Singapore, Jurgen Mihm, Jochen Schlapp

Many purchasing projects involve buying complex systems, which require the suppliers to perform some custom product or technology development regardless of whether they win the project or not. Viewing such a procurement setting through the lens of contest, we study under which circumstances a buying firm should source an integrated system or individual components.

#### 3 - Strategic Benefit of Request for Quotation

Ying Rong, Shanghai Jiao Tong University, No. 1 Lane 9, Yunwushan Road, Shanghai, 200051, China, Leon Zhu, Huan Zheng

We study how a buyer may reduce cost by combining a procurement process with (the threat of) exclusion clauses, the latter of which has been commonly adopted in contracting but rarely executed. We analyze the equilibrium outcomes when the buyer simultaneously or sequentially negotiates with imperfectly substitutable suppliers under a dual-sourcing setting. Surprisingly, the buyer can benefit from a request for quotation (RFQ) stage that precedes the negotiation stage even under a full information setting. Specifically, by endogenizing the sequence of negotiations via the quotations submitted, the buyer's equilibrium profit with an RFQ is (weakly) higher than the profit without an RFQ.

#### 4 - Supplier Competition and Investment: An Experimental Investigation

Cuihong Li, University of Connecticut, School of Business, 2100 Hillside Road, Storrs, CT, 06269, United States, Elena Katok, Zhixi Wan

We consider a buyer facing two suppliers who invest in cost reduction before bidding for contracts. Using laboratory experiments, we investigate how supplier competition and investment observability affect suppliers' cost-reduction and buyer's reserve price decisions.

## ■ TC18

North Bldg 128A

### Operations/ Marketing Interface I

Contributed Session

Chair: Franco Berbeglia, Tepper School of Business, 5000 Forbes Avenue, Pittsburgh, PA, 15213, United States

#### 1 - Channel-level Benefit-cost Analysis in Investment Decision

Yasamin Salmani, PhD Student, Drexel University, Philadelphia, PA, United States, Fariborz Partovi, Avijit Banerjee

Companies provide multiple sales channels for their customers, to compete in the marketplace. The model proposed in this study, helps the managers to have a channel-level profit analysis to improve these established sales channels.

#### 2 - Online Retailer Competition with Referral Services

Kihoon Kim, Korea University, Korea University Business School, LG-POSCO #316, Anam-dong, Seongbuk-gu, Seoul, 136701, Korea, Republic of

We investigate when two competing online retailers can be better off by adopting a referral service. We show that the proportion of the strongly loyal consumers of the referral-offering retailer in the group of its all consumers mainly determines the chance that the referral service will be adopted. As a main result, when the market shares of both the retailers are not significantly different, the referral service is likely to be adopted unless the degree of the loyalty among their loyal consumers is weak and there exist some comparison consumers.

#### 3 - The Strategic Impacts of Advertising on Crowdfunding

Zhixin Chen, Doctor, University of Technology and Science of China, Jinzhai RD 96#, Hefei, 230026, China, Jie Wu

Previous literature on crowdfunding paid rare attention to how advertising affects crowdfunding. To fill in this gap, we apply a stylized game-theoretical model to analyze interactions between firm's advertising decisions and crowdfunding decisions. As a result of our research, we obtained several managerial insights for the balance of the potential tension. The advertising is meaningless and the creator would choose to do no advertising when the fundraising target is relatively high, and the advertising can reduce the high price in menu pricing strategy, however, the menu pricing strategy can only work when the target is not too high.



**4 - Dynamic Salesforce Compensation**

Long Gao, University of California-Riverside, 900 University Avenue, 221 Anderson Hall, AGSM, Riverside, CA, 92521, United States

We study a salesforce compensation problem in a dynamic setting, where the salespeople have evolving skills and can learn over time. We characterize the optimal contract and derive the managerial implications.

**5 - Should Network Television Enable Consumer Binge Watching?**

Franco Berbeglia, PhD Candidate, Carnegie Mellon University, Tepper School of Business, 5000 Forbes Avenue, Pittsburgh, PA, 15213, United States, Timothy Derdenger, Kannan Srinivasan, Joseph Xu

With the broadcast television industry facing new forms of competition, networks have searched for new methods to distribute shows. Through the networks' online interfaces shows are able to match the new competitors and offer all-at-once releases rather than follow the traditional linear strategy. This lowers consumers' viewing costs, but also diminishes the viewer's responsiveness to advertising. This paper studies the impact of this new channel on network shows with a signaling model. We find the adoption of this channel is highly profitable for low quality shows, reducing the necessity of costly signaling through advertising for the high quality shows, which results in a more efficient market.

**■ TC19**

North Bldg 128B

**Topics in Dynamic Pricing and Revenue Management**

Sponsored: Revenue Management & Pricing

Sponsored Session

Chair: Vineet Goyal, Columbia University, New York, NY, 10027, United States

**1 - Aggregation Bias in Demand Estimation**

Zizhuo Wang, University of Minnesota, 1009 5th Street SE, Minneapolis, MN, 55414, United States, Chaolin Yang, Hongsong Yuan, Yaowu Zhang, Ruqing Jiang

Demand estimation is a core challenge in many industrial problems. In practice, companies often only have aggregate demand data in daily granularity, even though they may have changed prices within each day. A common approach in that case is to take a simple/weighted average of prices and use it as the price for each day (and the total demand as the demand for that day). However, such an approach may result in bias in demand estimation. In this work, we investigate under what conditions using such aggregate approach will result in an underestimation or an overestimation of price sensitivities. We also examine practical data from Alibaba to see the practical effects of demand estimation using aggregate data.

**2 - Customized Individual Promotions: Model, Optimization, and Prediction**

Srikanth Jagabathula, NYU Stern School of Business, 44 W. 4th St, Kmc Rm 8-74, New York, NY, 10012, United States, Dmitry Mitrofanov, Gustavo J. Vulcano

We propose a back-to-back procedure for running personalized promotions in retail operations contexts, from the construction of a nonparametric choice model where customer preferences are represented by directed acyclic graphs (DAGs) to the design of such promotions. We fit the models to historical purchases tagged by customer id, product availability and promotion data for a category of products. We provide new bounds for the likelihood of a DAG and show how to conduct the MNL estimation. We test our model to predict purchases at the customer individual level on real retail data. Finally, we illustrate how to use it to run personalized promotions.

**3 - Impact of Network Structure on New Service Pricing**

Vahideh Manshadi, Yale University, 165 Whitney Ave, Rm 3473, New Haven, CT, 06511, United States, Saed Alizamir, Ningyuan Chen, Sang-Hyun Kim

We analyze a firm's optimal pricing of a new service offering when the firm faces consumers who interact among themselves in a network and exert positive externality on each other. In order to maximize the long-run revenue generated from network externality, the firm provides its service for free initially to promote usage growth, raising the price when a sufficient level of consumer interactions is established. We study the impact of network structure on the firm's optimal pricing policy and revenue.

**4 - Dynamic Influence Maximization in Social Networks**

Shatian Wang, Columbia University, New York, NY, United States, Van-Anh Truong, Zhen Xu

We study algorithms for dynamically learning and spreading influence over social networks, by selecting the influencers in the network to incentivize.

**■ TC20**

North Bldg 129A

**Learning in Online Markets**

Sponsored: Revenue Management & Pricing

Sponsored Session

Chair: Negin Golrezaei, Massachusetts Institute of Technology, Cambridge, MA, 02142, United States

Chair: Santiago Balseiro, Columbia University, Columbia University, New York, NY, 10027, United States

**1 - Discontinuous Demand Functions: Estimation and Pricing**

N. Bora Keskin, Duke University, Fuqua School of Business, 100 Fuqua Drive, Durham, NC, 27708-0120, United States, Arnoud Victor den Boer

Price-rankings in online marketplaces and price comparison websites create discontinuities in demand functions. Motivated by this, we consider a dynamic pricing-and-estimation problem with an unknown and discontinuous demand function. We show that ignoring such discontinuities results in substantial loss of revenues, and construct near-optimal policies that can handle demand discontinuities.

**2 - Robust Repeated Auctions under Heterogeneous Buyer Behavior**

Shipra Agrawal, Columbia University, 500 West 120th Street, Mudd 423, New York, NY, 10027, United States, Konstantinos Daskalakis, Vahab Mirrokni, Balasubramanian Sivan

We study revenue optimization in a repeated auction between a single seller and a single buyer. Traditionally, the design of repeated auctions requires strong modeling assumptions about the bidder behavior, such as it being myopic, infinite lookahead, or some specific form of learning behavior. Is it possible to design mechanisms which are simultaneously optimal against a multitude of possible buyer behaviors? We answer this question by designing a simple state-based mechanism that is simultaneously approximately optimal against a k-lookahead buyer for all k, a buyer who is a no-regret learner, and a buyer who is a policy-regret learner.

**3 - Contextual Bandits with Cross-learning**

Jon Schneider, Google Research, New York, NY, United States, Santiago Balseiro, Negin Golrezaei, Mohammad Mahdian, Vahab Mirrokni

In the contextual bandits problem, in each round  $t$ , a learner observes some context  $c$ , chooses some action  $a$  to perform, and receives some reward  $r_{a,t}(c)$ . We study the variant of this problem where the learner also learns the values of  $r_{a,t}(c')$  for all other contexts  $c'$ . This variant arises in several strategic settings, such as learning how to bid in non-truthful repeated auctions. The best algorithms for the classical contextual bandits problem achieve  $O(\sqrt{CKT})$  regret against all stationary policies, where  $C$  is the number of contexts,  $K$  the number of actions, and  $T$  the number of rounds. We demonstrate algorithms for our variant that remove the dependence on  $C$  and achieve improved regret bounds.

**4 - Dynamic Pricing with Demand Learning and Reference Effects**

Arnoud den Boer, University of Amsterdam, Science Park 107, room F3.33, Amsterdam, Netherlands, N. Bora Keskin

We consider a dynamic pricing problem with demand learning and reference effects. Customers are loss averse: they have a reference price that can vary over time, and the demand reduction when the selling price exceeds the reference price dominates the demand increase when the selling price falls behind the reference price by the same amount. Consequently, the demand function has a time-varying "kink" and is not differentiable everywhere. The seller neither knows the underlying demand function nor observes the reference prices. We consider several variants of this problem and design asymptotically optimal pricing policies.

## ■ TC21

North Bldg 129B

### Joint Session RMP/Practice Curated: Data-driven Applications and Dynamic Learning in Revenue Management

Sponsored: Revenue Management & Pricing

Sponsored Session

Chair: N. Bora Keskin, Duke University, Durham, NC, 27708-0120, United States

#### 1 - The Exponential Choice Model: Assortment Optimization and Data-driven Applications

Jacob Feldman, Olin Business School, 6 Portland Court, Saint Louis, MO, 63108-1291, United States, Mohammed Ali Aouad, Danny Segev

We study the assortment optimization problem under the Exponential choice model. In this problem, a retailer seeks the revenue maximizing set of products to offer to each arriving customer. Our main contribution comes in the form of the first polynomial time approximation scheme with a provable guarantee for the assortment problem under the Exponential choice model. We follow up this result with a series of estimation studies using real data, which show that the predictive power of the Exponential model is on par with the classic MNL model.

#### 2 - Personalized Advertising and Learning Through High-dimensional Data with Limited Samples

Mingcheng Wei, University at Buffalo, 326C Jacobs Management Center, Buffalo, NY, 14260, United States, Xue Wang, Tao Yao

In this paper, we propose a Minimax Concave Penalized Multi-Armed Bandit algorithm for a decision-maker facing high-dimensional data with latent sparse structure in an online learning and decision-making process. This algorithm performs favorably compared to other algorithms, especially when there is a high level of data sparsity or when the sample size is not too large.

#### 3 - Data-driven Pricing for a New Product

Mengzhenyu Zhang, University of Michigan, Ross School of Business, Ann Arbor, MI, 48105, United States, Hyun-Soo Ahn, Joline Uichanco

Decisions regarding new products are difficult to make, and mistakes can have grave consequences to a firm's bottom line. Firms have little foresight on information about new product demand such as the potential market size, the rate of customers' adoption. We study the interplay between pricing and learning to maximize the expected revenue of a new product over a finite time horizon. We consider a setting where a firm can learn by observing sales data. To capture the stochastic adoption process, we develop a continuous-time Markovian Bass model. We derive the optimal pricing policy with learning and propose two simple and computationally tractable pricing policies that are provably near-optimal.

#### 4 - Dynamic Pricing-and-Learning Strategies in Service Operations

Yuan-Mao Kao, Duke University, Durham, NC, 27708, United States, N. Bora Keskin, Kevin Shang

We consider a firm providing a service to its customers under limited information about demand and service requirements. The firm can obtain more information by offering the service over multiple periods. In this setting, we formulate how pricing strategies affect the firm's learning, and we study the performance of near-optimal dynamic pricing strategies.

## ■ TC22

North Bldg 130

### Marketplace Innovation: Field and Empirical Studies

Sponsored: Revenue Management & Pricing

Sponsored Session

Chair: Chiara Farronato, Harvard Business School, Soldiers Field Road, Morgan Hall 412, Boston, MA, 02163, United States

#### 1 - Consumer Protection in an Online World: When Does Occupational Licensing Matter?

Chiara Farronato, Andrey Fradkin, Bradley Larsen, Erik Brynjolfsson

This paper studies the effects of occupational licensing on outcomes in a large online platform for home services, where professional service providers bid on consumers' projects. We exploit exogenous variation in the time at which licenses are displayed on the platform to identify the causal effects of licensing information and reviews on consumer choices. We find that platform verified licensing status is not valued by consumers but digital reputation is. Next, we use zip-code by job category variation in licensing stringency to measure the effects of licensing on aggregate market outcomes. Our results show that more stringent licensing leads to less competition and higher prices, but does not improve customer satisfaction.

#### 2 - Customer Preference and Station Network in the London Bike Share System

Pu He, Columbia University, Uris Hall, Cub 4H, New York, NY, 10027, United States, Fanyin Zheng, Elena Belavina, Karan Girotra

We study customer preference for the bike share system in the city of London. We estimate a structural demand model on the station network to learn the preference parameters and use the estimated model to provide insights on the design and expansion of the bike share system. We highlight the importance of network effects in understanding customer demand and evaluating expansion strategies of transportation networks. We develop a new method to deal with the endogeneity problem of the choice set in estimating demand for network products. Our method can be applied to other settings, in which the available set of products or services depends on demand.

## ■ TC23

North Bldg 131A

### Algorithmic Trading

Sponsored: Finance

Sponsored Session

Chair: Sebastian Jaimungal, University of Toronto, Toronto, ON, M5S3G3, Canada

#### 1 - Mean Field Games with Differing Beliefs for Algorithmic Trading

Sebastian Jaimungal, University of Toronto, Toronto, ON, Canada, Philippe Casgrain

Even when confronted with the same data, agents often disagree on a model of the real-world. Here, we address the question of how interacting heterogeneous agents, who disagree on what model the real-world follows, optimize their trading actions. The market has latent factors that drive prices, and agents account for the permanent impact they have on prices. This leads to a large stochastic game, where each agents' performance criteria is computed under a different probability measure. We analyse the mean-field game (MFG) limit of the stochastic game and show that the Nash equilibria is given by the solution to a non-standard vector-valued forward-backward stochastic differential equation. Under some mild assumptions, we construct the solution in terms of expectations of the filtered states. We prove the MFG strategy forms an  $\epsilon$ -Nash equilibrium for the finite player game. Lastly, we present a least-squares Monte Carlo based algorithm for computing the optimal control and illustrate the results through simulation in market where agents disagree on the model.

#### 2 - A Mathematical Analysis of Technical Analysis

Bin Zou, University of Connecticut, Storrs, CT, United States, Matthew Lorig, Zhou Zhou

In this paper, we study trading strategies based on exponential moving averages (ExpMA), an important indicator in technical analysis. We seek optimal ExpMA strategies when the drift of the underlying is modeled by either an Ornstein-Uhlenbeck process or a two-state continuous-time Markov chain. Closed-form solutions are obtained under the logarithm utility maximization and the long-term growth rate maximization.

#### 3 - Hedging Non-Tradable Risks with Transaction Costs and Price Impact

Ryan Donnelly, University of Washington, Seattle, WA, United States, Alvaro Cartea, Sebastian Jaimungal

An agent hedges exposure to a non-tradable risk factor  $U$  using a correlated traded asset  $S$  and accounts for the impact of trades on both factors. We obtain in closed-form the optimal strategy when the agent holds a linear position in  $U$ . With non-linear exposure to  $U$ , we provide an approximation to the optimal strategy in closed-form, and prove that the value function is correctly approximated when cross-impact and risk-aversion are small. With non-linear exposure, the approximate optimal strategy can be written in terms of the optimal strategy for linear exposure with the size of the position changing dynamically according to the exposure's "Delta" under a particular probability measure.

#### 4 - The Shadow Price of Latency: Improving Intraday Fill Ratios in Foreign Exchange Markets

Alvaro Cartea, University of Oxford, Oxford, United Kingdom, Leandro Sánchez-Betancourt, Philippe Casgrain

Liquidity takers face a moving target problem because of their latency. They send marketable orders that aim at a price and quantity they observed in the LOB, and by the time their order is processed, prices could have worsened (improved), so the order may not be filled (be filled at a better price). We show how to choose the discretion of orders to walk the LOB to increase the chances of filling them. The strategy balances the tradeoff between the costs of walking the LOB and targeting a percentage of filled orders. We employ prop data of FX trades to analyze the performance of the strategy and compute the price of latency that a trader would be willing to pay for co-location and hardware to reduce their latency.

## ■ TC24

North Bldg 131B

**eBusiness**

Sponsored: EBusiness

Sponsored Session

Chair: Ajit Sharma, Wayne State University, Rochester Hills, MI, 48307, United States

**1 - Signaling Quality with Return Insurance**

Chong Zhang, Tsinghua University, Beijing, China., Man Yu, Jian Chen

Motivated by sellers' practices on various shopping platforms such as Taobao.com and JD.com, we examine the informational role of a return insurance, which compensates consumers for their cost of returning the items. We characterize the conditions under which the return insurance can serve as an effective signal of high-quality products.

**2 - The Role of Filtered Search in Matching: Evidence From an Online Dating Platform**

Kyungmin Park, University of Washington, Seattle, WA, United States, Elina Hwang, Soo-Haeng Cho

Does filtered search really increase the matching probability in online dating market? Many online dating websites have utilized individual preference based filtering to improve their mate recommendation system. However, the effectiveness of the filtered search is questionable since stated and real preferences are often different. Based on the dataset from a Korean online dating website, we empirically examine the role of the filtered search on the matching probability in online dating market. Male users show a U-shaped pattern in the relationship between their mate search pool size and matching probability. Whereas, female users do not show any strong pattern.

**3 - Sponsor-Partner Relationship in Social Media Sponsored Contents**

Shahryar Doosti, University of Washington, Foster School of Business, Mackenzie Hall, Seattle, WA, 98195, United States, Stephanie Lee

Sponsored contents on social media have been major outlets for companies to advertise based on the targeted audience and popularity of the creators. We utilize a rich data set on sponsored videos on a large scaled social media to study the partnership between the sponsors and creators. We found that sponsors tend to keep the partnership over time despite the decaying efficiency in number of views.

**4 - The Role of Customer Images in Product Understanding**

Yue Guan, Tsinghua University, Beijing, China

Multimedia content has attracted increasing attention from customers, retailers and ecommerce platform managers. Compared with product images posted by retailers, images from customers are more trustworthy as a kind of UGC (User Generated Content). Drawing on the theory of consumer psychology, we aim to investigate the mechanism and elements in customer images that contribute to customers' product understanding. Empirical tests are conducted with real world data, and the significant effects of customer images are verified.

## ■ TC25

North Bldg 131C

**Data-driven Service Operations**

Sponsored: Service Science

Sponsored Session

Chair: Qiuping Yu, Kelley School of Business, Indiana University, Bloomington, IN, 47405-1701, United States

**1 - Does Feedback Make You Try Less Hard? A Study of Automotive Telematics**

Vivek Choudhary, INSEAD Business School, 1 Ayer Rajah Avenue, Singapore, Masha Shunko, Serguei Netessine

Internet of things devices and mobile connectivity in general increasingly enabling to track user behavior that was not possible before. In this paper we focus on insurance provided using automotive Telematics devices that track users' behavior while driving which is currently the most disruptive technology in the auto insurance industry. Using a novel dataset obtained through a collaboration with a startup, we find that contrary to the feedback and feedback-seeking literature, telematics feedback does not necessarily improve driving behavior.

**2 - Strategically Giving Service: The Effect of Real-time Information on Service Efficiency**

Nil Karacaoglu, Kellogg School of Management, Northwestern University, Antonio Moreno, Can Ozkan

The use of real-time information in on-demand services provides agents with access to an unprecedented amount of information about their competitors. We study the impact of the increased availability of real-time information on the behavior of strategic agents and the implications of this phenomenon for service efficiency using data from one of the leading e-hailing taxi platforms in South America

**3 - When More is Less: Staffing Level and Flexibility in a Restaurant Chain**

Masoud Kamalahmadi, Indiana University, 1309 E. 10th Street, Bloomington, IN, 47405, United States, Qiuping Yu, Yong-Pin Zhou

We empirically explore how staffing level and flexibility (created through unpredictable scheduling such as call-in and holdover overtime) impact worker and customer behavior, and subsequently the firm's current and future revenue. We find that working on holdover overtime negatively impacts worker productivity, whereas working on call-in doesn't impact worker productivity. Moreover, staffing decisions impact customers' current and future purchasing behaviors.

**4 - Ratings and Version Updates in the Mobile App Market**

Gad Allon, University of Pennsylvania, 3730 Walnut Street, Philadelphia, PA, 19104, United States, Kenneth Moon, Amandeep Singh

Mobile apps have become an economy with a projected market size of \$77 Billion in 2017. One of the key features that distinguishes mobile apps from other types of digital goods (such as movies, songs or books) is that they have versions. A developer can release an app into a mobile app store, and can then keep adding, removing, or editing features of the app with subsequent version updates. We characterize the optimal strategy for timing such updates and structurally estimate the extent to which developers respond to demand-side incentives in a ratings-sensitive environment. We discuss implications for platforms and developers.

## ■ TC26

North Bldg 132A

**Joint Session Service/Practice Curated: Empirical Research for New Service Business**

Sponsored: Service Science

Sponsored Session

Chair: Kejia Hu, Vanderbilt University, Nashville, TN, 37215, United States

**1 - Shaping Demand Peaks and Valleys in Service Industries Through Online Deals**

Simin Li, Kellogg School of Management, Northwestern University, 2211 Campus Drive, Evanston, IL, 60208, United States, Kejia Hu, Martin Lariviere

Using data from three leading online platforms in offering deals, we empirically study how service providers strategically design deals to facilitate demand-supply coordination during holiday demand swings. In particular, using our structural model, we find that service providers strategically design the deal discount and launch date based on their operating margin and foreseeable holiday demand change. Building on the estimation of deal customers' sensitivities to the discount and launch date, we propose an optimal deal strategy to shape demand and therefore increase profit. Moreover, we substantiate the importance of selecting a launch date wisely to manage demand and maximize profit.

**2 - The Impact of Waiting on Customer Response Delay**

Guangzhi Shang, Florida State University, College of Business, Tallahassee, FL, 32306, United States, Noyan Ilk

We study the impact of waiting times on customer response behavior in the context of online service centers. Using a unique operational data set, we show that waiting before service (i.e., queue wait) accelerates customer engagement, whereas waiting during service (i.e., in-service wait) slows down customer responses. These findings contribute to the service operations literature by showing the significance of the feedback from waiting to (customer-instigated) service time. We discuss the implications of these findings on customer admission decisions and agent workload levels.

**3 - Understanding Customers' Retrials in Call Centers: Preferences of Service Speed and Service Quality**

Kejia Hu, Vanderbilt University, 300 Ashcroft Pl, Nashville, TN, 37215, United States, Gad Allon, Achal Bassamboo

Using a call-by-call customers contact dataset, we want to understand how customers' preferences of service speed and quality impact their retrial behavior (calling back for the same issue) in the call center.



#### 4 - Need for Speed: The Impact of Website Performance on Online Retailers

Nil Karacaoglu, Kellogg School of Management, Evanston, IL, 60201, United States, Santiago Gallino, Antonio Moreno

In 2016, total online retail sales reached \$402.3 billion. Moreover, 49% of offline transactions are influenced by online channels. As the importance of online channels increased, the cost of webpage performance issues increased as well. In this environment, it is paramount for companies to understand how website performance impacts customer behavior and to determine the right balance between perceived website content quality and website performance. In this paper, we focus on how consumer behavior is affected by the performance of retailers' website. In particular, we analyze how website speed impacts conversion rates and online channel revenues.

#### 5 - Does Competition Improve Service Quality? The Case of Nursing Homes Where Public and Private Payers Coexist

Susan F. Lu, Purdue University, Krannert 441, West Lafayette, IN, 47907, United States, Konstantinos Serfes, Gerard Wedig, Bingxiao Wu

Competition plays an ambiguous role in markets for credence goods, where public and private payers coexist. Using nursing home data with a wide range of market structures, we find a U-shaped relationship between competition and service quality when nursing homes serve a mix of private and public segments, and a monotonic relationship when providers only serve the public segment. The outcomes can be explained by the interplay of two opposing effects of competition: the reputation building effect whereby competing firms choose high quality to build a good reputation and the rent extraction effect whereby competition hinders investment for quality improvements by eliminating price premia.

## ■ TC27

North Bldg 132B

### Joint Session PSOR/Practice Curated: Pro Bono Analytics Panel Discussion

Sponsored: Public Sector OR

Sponsored Session

Chair: David T. Hunt, Oliver Wyman, Oliver Wyman, Princeton, NJ, 08540, United States

#### 1 - Pro Bono Analytics Panel Session

David T. Hunt, Oliver Wyman, One University Square, Suite 100, Princeton, NJ, 08540, United States

Pro Bono Analytics (PBA) is an INFORMS program to match analytics professionals who are willing to volunteer their skills with nonprofit organizations that would benefit from analytical techniques. This panel session will begin with a brief description of some actual PBA projects, and will then focus on a discussion by volunteers and Phoenix area nonprofit representatives about the experiences and challenges of introducing analytics solutions into nonprofit organizations. The discussion will include defining the project outcome, overcoming data problems, and implementing the project results.

#### 2 - Using Decision Analysis to Evaluate Fund Raising for a Nonprofit Organization

David Krah, Kromite LLC, 243 N. Union Street, Lambertville, NJ, 08530, United States

#### 3 - Advancing the Analytics Capabilities at a Workforce Development Organization

Rozhin Doroudi, Northeastern University, Boston, MA, 02116, United States

#### 4 - Amanda Hope Rainbow Angels

Susan Santilena, Amanda Hope Rainbow Angels, Phoenix, AZ, United States

#### 5 - St. Mary's Food Bank

Marcos J. Gaucin, St. Mary's Food Bank Alliance, Phoenix, AZ, United States

## ■ TC28

North Bldg 221A

### Non-Monetary Mechanisms for Resource Allocation

Sponsored: Applied Probability

Sponsored Session

Chair: Siddhartha Banerjee, Cornell University, Ithaca, NY, 14853, United States

Co-Chair: Artur Gorokh, Cornell University, Ithaca, NY, 14850, United States

#### 1 - Bargaining and Maxmin Fairness

Anilesh Krishnaswamy, Stanford University, Stanford, CA, 94305, United States, Ashish Goel

While maxmin fairness is a well-known notion of fairness in many resource allocation problems, there is no known mechanism for its implementation in the standard bargaining setting. We construct a mechanism that implements the maxmin fair solution as the unique subgame perfect equilibrium in the n-player bargaining problem. We use the standard assumption, motivated in part by resource allocation problems, that any player can grab the entire surplus. Our mechanism consists of a binary game tree, with each node corresponding to a subgame where the players are allowed to choose between two outcomes. Our design crucially depends on novel combinatorial properties of the maxmin fair solution.

#### 2 - Multi-agent Mechanism Design Without Money

Huseyin Gurkan, Duke University, Fuqua School of Business, P.O. Box:337, Durham, NC, 27708, United States, Santiago Balseiro, Peng Sun

We consider a principal repeatedly allocating a single resource in each period to one of multiple agents, whose values are private, without relying on monetary payments over an infinite horizon with discounting. We design a dynamic mechanism without monetary transfers, which induces agents to report their values truthfully in each period via promises/threats of future favorable/unfavorable allocations. We show that our mechanism asymptotically achieves the first-best efficient allocation (the welfare-maximizing allocation as if values are public) as agents become more patient and provide sharp characterizations of convergence rates to first best as a function of the discount factor.

#### 3 - Dynamic Proportional Sharing: A Game-theoretic Approach

Seyed Majid Zahedi, Duke University, Durham, NC, United States

When agents pool their resources, each becomes entitled to a portion of the pool. In this talk, we show that mechanisms based on max-min fail to guarantee entitlements, strategy-proofness (SP) or both. We propose the flexible lending mechanism and show that it satisfies SP and guarantees at least half of the utility from static allocations while providing an asymptotic efficiency guarantee. Our results show that the performance of our mechanism is comparable to that of state-of-the-art mechanisms, providing agents with at least 0.98x, and on average 15x, of their utility from static allocations. Finally, we propose the T-period mechanism and prove that it guarantees SP and entitlements.

#### 4 - Non-Monetary Mechanism Design via Artificial Currencies

Artur Gorokh, Cornell University, Ithaca, NY, 14850, United States, Siddhartha Banerjee, Krishnamurthy Iyer

Non-monetary mechanisms for repeated resource allocation are gaining widespread use in many real-world settings. Our aim in this work is to study the allocative efficiency and incentive properties of simple repeated mechanisms based on artificial currencies. Our main result in this framework is a general black-box technique to convert any static monetary mechanism to a dynamic mechanism with artificial currency, that simultaneously guarantees vanishing loss in efficiency, and vanishing gains from non-truthful bidding over time.

## ■ TC28a

Foyer, North Bldg 221

### RAS Poster Session

Sponsored: Railway Applications

Sponsored Session

Chair: Andy Yoon, Norfolk Southern Corporation, Norfolk Southern Corporation, Suwanee, GA, 30024, United States

#### 1 - RAS Poster Session

Andy Yoon, Norfolk Southern Corporation, 867 Village Manor Pl, Suwanee, GA, 30024, United States

The RAS poster session provides an interactive way to share knowledge and state-of-the-art research in railroad applications. Poster presenters will have the opportunity to show case research or projects that are at early stages of development, and benefit from the interactive critique, suggestions, and encouragement from colleagues working in the area of railroad business analytics and optimization.

## ■ TC29

North Bldg 221B

**Modeling and Analysis of Emerging Mobility Services and Systems**

Sponsored: TSL/Urban Transportation

Sponsored Session

Chair: Yafeng Yin, University of Michigan, Ann Arbor, MI, 48109, United States

Co-Chair: Yu Nie, Northwestern University, Evanston, IL, 60208, United States

**1 - On the Supply Function of Ride-sourcing Systems**

Zhengtian Xu, University of Michigan, 2489 Stone Rd, Ann Arbor, MI, 48105-2540, United States, Yafeng Yin

For shared-use systems, an increasing number of users usually brings about positive network effects, by improving the efficiency on utilizing the shared resources. However, Castillo et al. (2017) identified a matching failure that may arise in a ride-sourcing system when experiencing surge of demand. It is shown that under the stated condition, the platform may match scarce idle drivers with those requesting customers very far away and thus waste substantial supply on picking them up. To better understand and measure the system performance, this study seeks to build up a supply function to associate the performance measures with other basic macro-indicators of a ride-sourcing system.

**2 - A Reservation Mechanism for Parking Slots Sharing Problems under Incomplete Information Setting**

Pengyu Yan, University of Electronic Science and Technology of China, Qingshuihe Campus: No.2006, Xiyuan Ave, West H, Chengdu, China, Heng He, Feng Chu, Debing Ni

Parking sharing applications have been launched to deal with parking challenges in many metropolitans. Motivated by industry and literature, this study addresses a novel reservation mechanism for parking sharing services under a real-time and incomplete information setting. A polynomial heuristic algorithm is developed to match and schedule parking resources for drivers. It is shown that self-interested drivers manipulate the reservation system via misreporting their demands with a parking-time-based pricing. Thus, a truth-telling pricing method based on VCG is designed, which achieve allocation efficiency, individual rationality, and budget balance economic properties as well.

**3 - An EABC Approach with Exact Loading and Unloading Strategies for Static Bike Repositioning Problem**C.S. Shui, University of Hong Kong, Composite Building, Seat 16, LG 208, Hong Kong, Hong Kong  
C.S. Shui, The University of Hong Kong Shenzhen Institute of Research and Innovation, Shenzhen, China, W. y. Szeto

This study investigates a bike repositioning problem (BRP) that determines the routes of the repositioning vehicles and the loading and unloading quantities at each bike station to firstly minimize the total demand dissatisfaction and then service time. To reduce the computation time to solve the loading and unloading sub-problem of the BRP, a novel set of loading and unloading strategies is proposed, proved to be optimal for a given route, and then embedded into an enhanced artificial bee colony algorithm to solve the BRP. Numerical studies show the computation efficiency of the proposed solution method and the trade-off between total demand dissatisfaction and the service time.

**4 - Street-hailing vs E-hailing: Modeling the Passenger Waiting Time of Personal Mobility Services**

Yu Nie, Northwestern University, A328 Technological Institute, 2145 Sheridan Road, Evanston, IL, 60208, United States, Kenan Zhang, Hongyu Chen

Mobile computing technologies have triggered the rapid development of Transportation Network Companies (TNC) in recent years. Although the e-hailing service provided by TNCs is normally believed to feature a higher matching efficiency, little is known about the underlying physics of passenger-driver meeting process. Based on the model developed in the previous work, this study investigates the passenger waiting time of both street-hailing and e-hailing. Taxi trajectories and TNC operating data collected in Shenzhen, China are used to validate the model and to compare the passenger waiting time under various scenarios.

## ■ TC31

North Bldg 222A

**Joint Session TSL/Practice Curated: Traffic Models and Applications with Emerging Data Sources**

Sponsored: TSL/Intelligent Transportation Systems (ITS)

Sponsored Session

Chair: Goktug Islamoglu, Captura ITS, Cengelkoy Mah. Kalantor Sok., 16/3 Uskudar, Istanbul, 34680, Turkey

**1 - Efficient Collection of Connected Vehicles Data with Precision Guarantees**

Negin Alemazkoo, University of Illinois at Urbana-Champaign, Champaign, IL, United States, Hadi Meidani

Connected vehicles disseminate detailed data with a very high frequency. Therefore, efficient collection of data is critical to prevent overburdening the communication systems. We propose an efficient data collection scheme that selects and transmits only a small subset of data. We have tested the proposed approach to select data points to be transmitted from 10,000 connected vehicles trips. Results show that collection ratio can be as small as 0.05. A simulation study was also performed to evaluate travel time estimation accuracy using the proposed data collection approach. Results show that the proposed approach can significantly improve travel time estimation accuracy.

**2 - Inferring High Resolution Individual Activity and Trip Purpose From GPS Trajectories Data Collected from a Navigation App**

Shin-Yu Lin, Metropia, 1790 E. River Rd., Suite 140, Tucson, AZ, 85718, United States, Ali Arian, Ali Arian, Alireza Ermagun, Yi-Chang Chiu

Traditionally human mobility patterns and space activities are studied using recall-based travel diaries. Following the ubiquity of location-based technologies, transportation researchers are revisiting the methods of classifying travel activity patterns using geo-location data. The current study contributes to this research line by leveraging granular and detailed activity information collected from a navigation app, Metropia.

**3 - Traffic Synchronization Protocol: Ising Model Phase Transitions in Hyperbolic Lattices of Accidents**

Goktug Islamoglu, Pamir, Cengelkoy Mah. Kalantor Sok. 16/3 Uskudar, Istanbul, 34680, Turkey

When Turkey's annual accident-vehicle graph is plotted from 1986 to 2016, the points form a spiral expanding around the regression line. Spiral symmetry breaks for all vehicle types except for LCVs (light commercial vehicles), implying a nonlinear dynamic behavior coexisting with the strong linear dependence of accidents to the number of vehicles. Its projection on a 2D cellular automaton through hyperbolic geometry exhibits a Tracy-Widom distribution and provides closed form solutions of the Ising Model. Emergence of accident formations in non-human sources of error suggest the need for a "synchronization protocol of autonomous vehicles, which are developed with the human error assumption.

## ■ TC32

North Bldg 222B

**Supply Chain Design and Operations II**

Sponsored: TSL/Freight Transportation &amp; Logistics

Sponsored Session

Chair: Burcu B. Keskin, University of Alabama, Tuscaloosa, AL, 35406, United States

**1 - Designing a Centralized Distribution System for Omnichannel Retailing**

Jia Guo, University of Alabama, Tuscaloosa, AL, 35487-0226, United States, Burcu B. Keskin

We focus on supply chain design and omnichannel strategies with demand segmentation, cost structure, and more importantly, the company's execution ability. We formulate our problem as a two-stage stochastic programming model and use first-order optimality conditions to study the optimal inventory replenishment decisions. The omnichannel strategy decisions are made by analyzing the expected profit. We show that omnichannel strategies are not necessarily profitable for all retailers. Imperfect demand may result in losing the inventory pooling benefits when running omnichannel strategies.

**2 - Try Before You Buy: Membership Program of Competing E-retailers**

Amy Pan, University of Florida, FL, United States, Gang Li, Ming Jin

With the increasingly convenience of online shopping, more and more consumers prefer to make purchases from e-retailers. However, the disadvantage of the inability to try on and the need to wait for delivery still exists. Some e-retailers have implemented the try-before-you-buy (TBYB) program, which allows consumers to try on products at home to resolve the valuation uncertainty before making a purchase. We develop a theoretical model where two e-retailers may opt for TBYB program and find that the TBYB can soften the competition and increase consumer surplus.

**3 - Benders Decomposition for Supply Chain Network Design**

Simon Belieres, LAAS-CNRS, 7 Avenue du Colonel Roche, Toulouse, 31400, France, Mike Hewitt, Tom Van Woensel, Nicolas Jozefowicz, Frederic Semet

We consider a large-scale supply chain that must satisfy recurring customer

requests for products, wherein the sizes of products are small enough for consolidation to be an option. To serve these requests, the carrier can solve a variant of the Service Network Design problem wherein each commodity has multiple potential origins. Industrial instances involve a significant number of products, which in turn yields a model that is larger than an off-the-shelf solver can handle. We present a Benders method with a master problem defined over aggregated products. We augment this approach with valid inequalities and heuristics, and with an extensive computational study illustrating its effectiveness.

## ■ TC33

North Bldg 222C

### Big Data and Machine Learning for Advanced Manufacturing

Emerging Topic: OR and Advanced Manufacturing

Emerging Topic Session

Chair: Guha Manogharan, Pennsylvania State University, University Park, PA, United States

Co-Chair: Michael G. Kay, North Carolina State University, Raleigh, NC, 27695, United States

#### 1 - Uncertainty Quantification for Integrated Simulation Models with Unobservable Variables Using Bayesian Networks

Mohamad Mahmoudi, Texas A&M University, 1221 April Bloom, A, College Station, TX, 77840, United States, Alaa Elwany

In this work we investigate the problem of uncertainty quantification for a system of computer models which are integrated in a hierarchical fashion. We consider the assumption of existence of unobservable outputs in our system. The proposed methodology employs Bayesian networks to conduct uncertainty quantification. To evaluate the performance of the proposed method, a case study of simulation models used in metal additive manufacturing is presented where two high-fidelity models are integrated and uncertainty sources for each model is identified. The results of using the Bayesian network for uncertainty quantification is the presented and thoroughly discussed.

#### 2 - Revitalizing Sand-Casting Supply Chain in the United States: A Study on Locating 3D-Sand Printer Hubs to Support Metal Foundries

Michael Kay, Pennsylvania State University, 232 Reber Building, State College, PA, 16802, United States, Ramin Ahmed, Casey Bates, Paul Lynch, Guha Prasanna Manogharan

Additive manufacturing (AM), over the past few years, has played a revolutionary role in the field of manufacturing, mainly in the casting process. In casting industries, sand casting provides huge scope due to its expandability and ability to create complex metal parts of almost any alloy. Recent research has determined various benefits of 3D printing sand molds including time efficiency, minimizing product and development delay, the ability to form very intricate castings, reduction in the need for inventory and so on. While all these benefits are apparent, traditional manufacturers are still not encouraged to adopt only due to its high fixed cost and lack of expertise. On the other hand, there are so much demand over the U.S it is hard only a handful of dedicated AM firms to the demand points. This is due to the fact that, the transportation cost will become prohibitive due to the fragile nature of the sand molds. In this paper, we investigate a system of strategically-located AM hubs which can encompass all the demand points. Using North American Industry Classification System (NAICS) data for the foundries in the U.S., we have used an uncapacitated facility location model to determine the optimal locations for AM hubs where we considered the geographic data and demand and strategically identified the fixed cost using various data like AM machine cost, packaging cost, employee salaries, rent and other consumables which were obtained through personal communication. Results from this study will identify: (a) candidate US counties to build AM hubs, (b) total cost (fixed, operational and transportation). We also noticed that over the past years the demand has been increasing, which would mean an increased capacity to satisfy those demand. We hope to address this issue with a sensitivity analysis in 3 levels: (low, medium, high). With each such level of increase, we aim to demonstrate how and where the additional hubs should be added.

## ■ TC34

North Bldg 223

### 12:05 - 12:50 Optimization Firm/ 12:50 - 1:35 MathWorks

Emerging Topic: Technology Tutorials

Emerging Topic Session

#### 1 - Experiential Machine Learning with MATLAB

Elvira Osuna-Highley, Mathworks, Natick, MA, United States

There is a growing need to teach the next generation of scientists and engineers ever more complex concepts. It is critical that intuition is built quickly so that

they can apply their knowledge to develop the technology of the future. This calls for experiential learning techniques that make concepts easy and fun to teach, learn and test. This tutorial will illustrate experiential learning using the Classification Learner app in MATLAB. You will see how to work through modules in MATLAB in order to build various classification models. This will give you the opportunity to understand the potential for using an experiential approach in the classroom as well as introducing you to tools that you may use in your research.

#### 2 - MathWorks – Information not available.

## ■ TC35

North Bldg 224A

### Urban Air Mobility

Sponsored: Aviation Applications

Sponsored Session

Chair: Peng Wei, Iowa State University, Ames, IA, 50011, United States

#### 1 - Energy Optimal Speed Profile for Arrival of Tandem Tilt-Wing eVTOL Aircraft with RTA Constraint

Priyank Pradeep, Iowa State University, Ames, IA, 50011, United States, Peng Wei

The electric vertical takeoff and landing (eVTOL) aircraft can alleviate transportation congestion on the ground by utilizing three-dimensional airspace efficiently. However, the endurance of Lithium-ion Polymer (Li-Po) batteries imposes severe constraints on the operational time span of an eVTOL on urban air mobility (UAM) passenger transportation mission. This research focuses on the problem formulation and numerical solution of a fixed final time multiphase optimal control problem with energy consumption as the performance index for a tandem tilt-wing eVTOL.

#### 2 - Adaptive Arrival Sequencing and Scheduling for Mixed Fleet eVTOL Aircraft in On-Demand Urban Air Mobility

Priyank Pradeep, Iowa State University, Ames, IA, 50011, United States

Our current research is focussed on solving Aircraft Sequencing and Scheduling (ASS) problem for eVTOL aircraft in Urban Air Mobility (UAM) environment. The concept of operations (CONOPs) for both types of eVTOL aircraft (wingless and winged) is assumed to be cruising at constant altitude followed by the vertical descent. To compute the set of RTAs, first, the sequencing order of landing of the eVTOL aircraft will be calculated using heuristic methods, such as Genetic Algorithm (GA). Once we determine an arrival sequencing order, the arrival scheduling sub-problem can be formulated as mixed integer linear programming (MILP) problem and will be solved using open source MILP solver Gurobi Optimizer.

#### 3 - Autonomous On-Demand Free Flight Operations in Urban Air Mobility using Monte Carlo Tree Search

Xuxi Yang, Iowa State University, Ames, IA, 50011, United States, Peng Wei

Vertical takeoff and landing (VTOL) aircraft for on-demand air taxi will bring fundamental changes to daily commutes. NASA, Uber, and Airbus have been exploring the exciting concept of Urban Air Mobility (UAM). In order to enable safe and efficient autonomous on-demand free flight operations in this UAM concept, a computational guidance algorithm was designed and analyzed with collision avoidance capability. The approach is to formulate this problem as a Markov Decision Process and solve it using Monte Carlo Tree Search. A simplified numerical experiment was created and results show that this algorithm can help aircraft quickly reach the trip destination and avoid conflicts with other aircraft.

#### 4 - Innovating Airline Operations Centers to Support New Fleet Demands

Victoria C. Nneji, Duke University, Durham, NC, 27708, United States

Several manufacturers are developing new vehicles for high-speed intra-city air taxi on-demand mobility (ODM) services. With diverse vehicle design requirements, how might airline operations centers need to innovate to support these new fleet demands? We used task- and time-based data from a collective case study of dispatchers to develop a discrete event simulation to serve as a predictive model of human-system performance in these air operations centers. With this tool, companies can rapidly prototype future ODM concepts of operations to make better informed strategic, tactical, and operational decisions in staffing and designing centers.

#### 5 - A Progressive Trajectory Planning Algorithm for High-Density 2D Traffic

Yanchao Liu, Wayne State University, Detroit, MI, United States

This talk presents a trajectory planning algorithm based on nonlinear optimization techniques. The model centrally coordinates trajectories for all vehicles traversing a shared two-dimensional space. To avoid path deadlocks associated with local optima, a progressive solution algorithm is developed. In addition, a set of new metrics is proposed to measure traffic flow efficiency of 2D transit systems. Simulation results will be demonstrated.



## ■ TC36

North Bldg 224B

**Joint Session Drones/Practice Curated:  
Operations Research Applications in Drones**

Emerging Topic: Robotics, Drones and Autonomous Vehicles in Logistics

Emerging Topic Session

Chair: Gino Lim, University of Houston, Houston TX

Co-Chair: Seon Jin Kim, University of Houston, Houston, TX, 77094, United States

**1 - A Hybrid Approach for Extending Drone Flight Duration in Real Time**

Seon Jin Kim, University of Houston, 422 Cypress Vista, Houston, TX, 77094, United States, Gino J. Lim

This study focuses on continuous flight missions using battery powered drones. There are two types of battery charging techniques: stationary and dynamic wireless charging systems. However, the stationary system requires frequent visits of drones to the ground control center to replace or charge the batteries, while the dynamic system does not have reliable battery charging efficiency. To overcome both of these issues in a battery charging system, a hybrid battery charging system combining stationary and dynamic wireless charging systems has been proposed.

**2 - Carrier-drone Vehicle Routing Problem: Multiple Deliveries by a Single Flight**

Ho-Young Jeong, Purdue University, 315 N. Grant St, West Lafayette, IN, 47907, United States, Seokcheon Lee

A carrier-drone hybrid delivery vehicle uses a truck as a station for delivery drones. The truck with a larger cargo capacity carries and launches drones to customers in locations where traffic congestions or physical obstructions are present. Because of its significant advantages, various hybrid routing models have recently been proposed and researched. We'd like to introduce a new model that allows drones to make multiple deliveries by a single flight. This property is expected to further enhance logistical efficiency compared to existing models limited to single delivery per flight. In this study, this new hybrid vehicle routing problem is presented along with evidence of its practicality.

**3 - Operation Based Vehicle Routing Problem for Drone Assisted Truck Delivery**

Jinkun Lee, East Carolina University, Greenville, NC, United States, Sung Hoon Chung

We consider a drone assisted truck delivery problem where the truck serves as a mobile station of single or multiple drones while delivering items to customers at the same time. We formulate the model as a mixed integer programming problem where the objective is to minimize the total delivery time. We describe the pre-process of the exact algorithm where the possible operations, defined as drone-truck delivery combination units, are identified to reduce the overall computational complexity. We present case studies and discuss efficacy and efficiency of the proposed approach.

**4 - Deliver or Not?: Revenue and Capacity Management for Drone-based Delivery Services**

Zhangchen Hu, University of Massachusetts Amherst, Amherst, MA, 01003, United States, Heng Chen, Senay Solak

Drones are expected to become a key component of commercial delivery services for retailers and courier companies in the near future. Using currently available data, we develop both queueing-based and dynamic programming-based models to determine when drone delivery options should be enabled by retailers. Both analytical and numerical analyses are provided.

**5 - An Unmanned Aircraft System Path Planning Model for Inspecting Wind Turbines**

Hyeoncheol Baik, PhD Candidate, Auburn University, Shelby 3301, Auburn, AL, 36849, United States, Jorge F. Valenzuela

Rope access is a common technique for maintaining and servicing wind turbines. This technique is risky and inefficient. An alternative approach is to use an unmanned aircraft system (UAS). The challenge is to determine an efficient way to deploy the UAS over a region with multiple wind turbines. In this presentation, we describe a mathematical programming path planning model for a UAS that works cooperatively with a ground vehicle. The objective of the model is to minimize the total inspection time. We use a real wind farm to test our model.

## ■ TC37

North Bldg 225A

**Recent Advances in Applied Probability**

Sponsored: Applied Probability

Sponsored Session

Chair: Jose Blanchet, Columbia University, New York, NY, 10027, United States

**1 - Nonconvex Optimization via Accelerated Langevin Diffusion**

Yi Chen, Northwestern University, Evanston, IL, United States

Nonconvex optimization arises from numerous machine learning problems. However, due to the existence of spurious local minima, nonconvex optimization remains challenging in both theory and practice. We investigate the method of solving optimization via Langevin diffusion. We consider some techniques accelerating the convergence, which enable us to obtain a better solution within a shorter time.

**2 - Even Faster Algorithms for Optimal Transport**

Carson Kent, Stanford University

Over the past decade, optimal transport and Wasserstein metrics have come to play a major role in a wide variety of tasks throughout optimization and machine learning- e.g. resource allocation problems, unsupervised learning, distributionally-robust optimization, etc. Typically, a major bottleneck for these applications is the computation of a transportation plan between discretized measures. Recent algorithmic advances have resulted in a bevy of new methods for this problem which have linear-time complexity guarantees and can scale to large problem sizes. In this work, we will present several new developments in this lineage of results which obtain superior complexity/performance. Additionally, we will provide perspective for where further computational improvements for this problem are likely and unlikely to be found.

**3 - Space-filling Design for Nonlinear Models**

Chang-Han Rhee, Centrum Wiskunde and Informatica, Jakoba Mulderplein 164, Amsterdam, 1018 MZ, Netherlands, Enlu Zhou, Peng Qiu

Traditional space-filling designs for computer experiments aim to fill the parameter space with design points that are as "uniform as possible. However, the resulting design points may be non-uniform in the model output space failing to provide a reliable representation of the output manifold, and becoming highly inefficient or even misleading in case the computer experiments are non-linear. In this talk, we propose and analyze an iterative algorithm that fills in the model output manifold uniformly rather than the parameter space uniformly so that one could obtain a reliable understanding of the model behaviors with the minimal number of design points.

**4 - Approximating Performance Measures for Non-stationary Markov Chains**

Zeyu Zheng, Stanford University, Stanford, CA, 94305, United States, Harsha Honnappa, Peter W. Glynn

Non-stationarity naturally arises in realistic modeling of many problems in operations research and operations management. Unfortunately, the development of closed-form theory for the great majority of stochastic models requires an assumption of stationary dynamics. We develop rigorous approximations to various expectations associated with generic non-stationary Markov models. These approximations are typically no harder to compute, either analytically or numerically, than are the linear systems associated with the stationary case. Asymptotic validity is established with slowly changing transition probabilities (which is only required over a small portion of the entire horizon).

## ■ TC38

North Bldg 225B

**APS-Special Speaker Session**

Sponsored: Applied Probability

Sponsored Session

Chair: Henry Lam, Columbia University, New York, NY, 10027, United States

Chair: Harsha Honnappa, Purdue University, Purdue University, West Lafayette, IN, 47906, United States

**1 - Maintaining Privacy in Statistical Estimation: Definitions, Optimality, and Estimators**

John Duchi, Department of Statistics - 390 Serra Mall, Stanford University, Stanford, CA, 94305, United States

In this tutorial, I will describe the techniques for maintaining privacy in statistical estimation, machine learning, and stochastic optimization. I will begin the tutorial with several recent definitions, beginning with differential privacy, and describe their implications. After this, I will describe several recently developed tools for deriving optimal estimators, and give examples of their use in theory and practice, including machine learning, statistical, and optimization applications.

## ■ TC39

North Bldg 226A

## Probability Models in a Shared Economy

Sponsored: Applied Probability

Sponsored Session

Chair: Mariana Olvera-Cravioto, University of California-Berkeley, Berkeley, CA, 94720, United States

### 1 - Last-mile Shared Delivery: A Discrete Sequential Packing Approach

Junyu Cao, University of California-Berkeley, Berkeley, CA, 94720, United States, Mariana Olvera-Cravioto, Max Shen, Max Shen

We propose a model for optimizing the last-mile delivery of  $n$  packages from a distribution center to their final recipients, using a strategy that combines the use of ride-sharing platforms (e.g. Uber or Lyft) with a traditional van infrastructure. Our technical approach is based on the formulation of a discrete sequential packing problem, which is closely related to Renyi's parking problem. The main objective is to compute the optimal reward offered to private drivers for each individual package in a way that minimizes the total expected cost for delivering all packages. We show that under natural assumptions our mixed strategy can achieve significant improvements compared to a van-only strategy.

### 2 - Taxi-customer Queues with Delayed Matching

Lu Wang, University of North Carolina at Chapel Hill, B52 Hanes Hall, Chapel Hill, NC, 27599, United States, Vidyadhar Kulkarni

We consider a network of taxis and customers with Poisson arrivals and exponential patience times. We assume that there are exponentially distributed delays in matching the taxis with customers. We establish two methods to compute the fluid and diffusion approximations for the queue lengths and compare their performance.

### 3 - Customer Preference and Station Network in the London Bike Share System

Pu He, Columbia University, Uris Hall, Cub 4H, New York, NY, 10027, United States, Fanyin Zheng, Elena Belavina, Karan Girotra

We study customer preference for the bike share system in the city of London. We estimate a structural demand model on the station network to learn the preference parameters and use the estimated model to provide insights on the design and expansion of the bike share system. We highlight the importance of network effects in understanding customer demand and evaluating expansion strategies of transportation networks. We develop a new method to deal with the endogeneity problem of the choice set in estimating demand for network products. Our method can be applied to other settings, in which the available set of products or services depends on demand.

### 4 - Managing Services with Dependent Valuations and Service times

Achal Bassamboo, Ohad Perry, Chenguang Wu

The valuation for service of an arriving customer often depends on his individual service requirement; in this work we consider a queueing model in which these two random variables are stochastically dependent. Specifically, customers are price and delay sensitive, and decide whether to queue for service based on their service valuations, waiting cost and the price of service. Employing a general dependence order, we show that the provider's optimal revenue decreases with the strength of the dependence. Moreover, considering the valuation and service requirement to be independent when they are in fact dependent can lead to substantial revenue losses.

## TC40

North Bldg 226B

## Risk and Decision Analysis for the Resilience of Infrastructure Systems and Communities

Sponsored: Decision Analysis

Sponsored Session

Chair: Hiba Baroud, Vanderbilt University, Nashville, TN, 37235, United States

### 1 - Modeling Risks of Extreme Weather Induced Power Outages

Sayanti Mukherjee, Assistant Professor, University at Buffalo, Buffalo, NY, 14260, United States

Weather extremes cause sustained power outages that affect millions of people, causing extensive economic losses every year. The importance of building electricity sector's resilience, and thereby enhancing its service-security and long-term economic benefits is well established. To characterize the key predictors of such power outages, we propose a multihazard risk estimation approach. Our model suggests that power outage risk is a function of hazard types, expanse of overhead power systems, expanse of rural or urban areas, and levels of investment in operations/maintenance activities. The proposed model can help utility regulators to make risk-informed resilience investment decisions.

### 2 - A Multiple Decision-maker Approach to Allocating Resources for

## Disruptive Events

Cameron MacKenzie, Iowa State University, 3029 Black Engineering, Industrial and Manufacturing Systems Eng, Ames, IA, 50011, United States, Brandon Landowski

Most decision-making models for disruptive events and resilience consider a single decision maker. However, building community resilience and preparing and responding to disruptive events involve multiple stakeholders and different decision makers. We create different resource allocation models for different decision makers preparing and responding to a disruptive event. The decision makers include the federal government, state government, private sector, and non-governmental organization. We explore how the benefits of cooperating among these decision makers can increase the effectiveness of allocating resources to prepare and respond to disruptive events.

### 3 - Climate Analysis Support Tool for Community Resilience Assessment & Adaptation Planning

Leslie Gillespie-Marthaler, Vanderbilt University, 512 Cedar Cove, Nashville, TN, 37209, United States, Hiba Baroud

Communities require methods to aid in use of data related to climate change, as well as means to apply scenario-based alternatives to current and future decision making processes. To this end, we have developed a scalable tool using downscaled CMIP5 multi-model ensemble outputs, Rstudio, and local data to assess how extreme events may change in the future. The tool can be used to develop possible scenarios related to changes in frequency and magnitude for extreme precipitation (100, 200, 500 year) events. Outputs from the tool will be used in assessing community resilience to flood for a test community to build strategies that enhance current and future survival, wellbeing, and sustainable resilience.

### 4 - Optimal Inspection Strategies for Turbine Runners in Hydropower Plants

Andreas Kleiven, PhD Student, Norwegian University of Science and Technology, Alfred Getz vei 3, Trondheim, 7491, Norway, Stein-Erik Fleten, Carl Ullrich, Benjamin Fram

We develop a model for stochastically deteriorating turbine runners in hydropower plants with the purpose of finding the implied cost of inspections. Unscheduled downtime caused by failure of critical components in a hydropower plant may cause huge revenue losses. Inspections give information about the system state, and maintenance actions can be planned accordingly. In this work we simulate and analyze an inspection and replacement strategy based on turbine data from Norwegian hydropower plants.

## TC41

North Bldg 226C

## Participatory Modeling

Sponsored: Decision Analysis

Sponsored Session

Chair: Karen Jenni, U.S. Geological Survey, DFC, MS 939, Denver, CO, 80225, United States

Co-Chair: Antonie Jetter, Portland State University, Portland, OR, United States

### 1 - Tools and Methods in Participatory Modeling

Karen Jenni, U.S. Geological Survey, DFC, MS 939, Denver, CO, 80225, United States, Alexey Voinov, Steven Gray, Pierre Glynn, National SESYNC Participatory Modeling Working Group

The diversity of tools and methods used in participatory modeling can create challenges for stakeholders and modelers when selecting the ones most appropriate for their projects. We offer a systematic overview, assessment, and categorization of methods to assist modelers and stakeholders with their choices and decisions. Based on the results of our Participatory Modeling Working Group, and a survey of modelers engaged in participatory processes, we offer practical guidelines to improve decisions about method selection at different stages of the participatory modeling process.

### 2 - Participatory Exploratory Modelling and Analysis with Fuzzy Cognitive Maps

Antonie J. Jetter, Portland State University, ETM Department, 1900 SW 4th Ave, Portland, OR, 97207, United States

Participatory modelling pools participants' partial system knowledge, often resulting in "deep uncertainty" because some aspects of the system structure remain unknown. Exploratory modeling and analysis (EMA) simulates system behavior for multiple unknown inputs and alternative system structures. We illustrate a novel approach to combine EMA with Fuzzy Cognitive Mapping with two studies, which used different methods to determine the range of "deep uncertainty", namely content analysis and expert surveys. We present data collection and EMA approaches, computational challenges, results, and lessons learned for these strategies.

### 3 - A Participatory Model for Improving Safety Culture in Oil and Gas Operations

Antonie J. Jetter, Portland State University, ETM Department,  
1900 SW 4th Ave, Portland, OR, 97207, United States,  
Ahmed Alibage

Participatory modeling often occurs when the system under study is poorly understood and quantified. A case in point is safety culture, which describes the values, routines, and work processes that allow an organization to prevent disasters by avoiding and quickly bouncing back from mistakes. It is particularly relevant in oil and gas industry, where initially small errors can have devastating impacts. Relevant quantitative data on safety culture is virtually non-existent and practitioners have to rely on research findings in other context and their own observations: our work uses thematic analysis, t-coefficient, and Fuzzy Cognitive Mapping to create a model based on these knowledge sources.

#### 4 - Twelve Questions for the Participatory Modeling Community

Steven Gray, Michigan State University, Amherst, MI,  
United States, Antonie J. Jetter, Karen Jenni

Participatory modeling engages the implicit and explicit knowledge of stakeholders to create formalized and shared representations of reality, and has evolved into a field of study as well as a practice. Participatory modeling researchers and practitioners who focus specifically on environmental resources met at the National Socio-Environmental Synthesis Center (SESYN) in Annapolis, Maryland, over the course of two years to discuss the state of the field and future directions for participatory modeling. We will present a description of 12 overarching groups of questions that could guide future inquiry.

## ■ TC42

North Bldg 227A

### Joint Session Analytics/Practice Curated: Impactful Applications of Analytics in Industry

Sponsored: Analytics

Sponsored Session

Chair: Subrat Sahu, Caterpillar Inc, Peoria, IL, United States

#### 1 - Operationalizing a Customer Retention Framework in Logistics Industry

Swapnil Srivastava

No Abstract Available.

#### 2 - Operations Research and Mathematical Sciences becomes Pervasive on a Networked, Collaborative Platform

Ben Amaba, IBM

Ben Amaba, University of Miami, Miami, FL, United States

Mathematical modeling has provided a competitive advantage for institutions to aid in understanding, learning, decision making, forecasting and operations. As the number of sensors, smart phones, Internet of Things (IoT), robots, blockchain and other data sources grow, the discipline and methods become foundational on a platform to manage complexity. The power of processors, better networks, less expensive memory and disk space, and better user interfaces are making data sciences accessible to more individuals on an open, secured platform where reuse and collaboration allows users to combine artificial intelligence and other technologies to advance operations research application.

## ■ TC43

North Bldg 227B

### Machine Learning to Facilitate Renewable Integration in Power Grids

Emerging Topic: Energy and Climate

Emerging Topic Session

Chair: Vaidyanathan Krishnamurthy, University of Pittsburgh, PA, United States

Co- Chair: Jeff Manning, MSEE, University of Texas, Austin, TX, 78750, United States

#### 1 - Multi Energy Storage Systems Control Using Multi Agent Reinforcement Learning

Heechang Ryu, Korea Advanced Institute of Science and Technology, 3120 Ho, E2-2., KAIST, 291, Daehak-Ro, Daejeon, 34141, Korea, Republic of, Jinkyoo Park

Energy storage systems (ESSs) can resolve the temporary imbalance in microgrid with a renewable energy source. Finding the optimal charging and discharging schedule of an ESS is essential. In particular, it is very challenging to optimally control each ESS when multiple households have their own ESSs and renewable energy sources. In this study, we show that these ESSs are controlled by using multi-agent reinforcement learning as a data-driven method. In addition, it is validated through a numerical simulation study with real data.

#### 2 - Multi-Tasks Bayesian Optimization Approach to Demand Response Management in Smart Grid

Jinkyoo Park, PhD, Korea Advanced Institute of Science and Technology, Daejeon, 34141, Korea, Republic of

No abstract available.

#### 3 - Forecasting Variability in Local Area Photovoltaic Power Generation by Sparse Identification Nonlinear Dynamics of Cumulus Clouds

Jeff Manning, University of Texas, RASTRAC, 13809 Research Boulevard, Austin, TX, 78750, United States

We propose and investigate the tractability of prediction of the temporospatial evolution of fair-weather cumulus clouds affecting the power production of a local photovoltaic generation site, by discovering a governing partial differential equation from data alone, in a convenient sequential photographic measurement basis. Clouds in such conditions have lifetimes ranging from five to thirty minutes, so a predictor must account for cloud evolution in addition to mere horizontal advection. The design is challenged by observability limitations, so we investigate alternative, but similar approaches.

## ■ TC44

North Bldg 227C

### Improving System Flexibility and Robustness Through Advanced Computation

Sponsored: Energy, Natural Res & the Environment/Electricity

Sponsored Session

Chair: Shmuel S. Oren, University of California-Berkeley, Berkeley, CA, 94720-1777, United States

Co-Chair: Georgios Patsakis, University of California Berkeley, Berkeley, CA, 94702, United States

#### 1 - Recovery of Locally Optimal Solutions From Convex Relaxations of the AC Optimal Power Flow

Andreas Venzke, Technical University of Denmark, Kgs. Lyngby, Denmark, Daniel K. Molzahn, Spyros Chatzivasileiadis

Convex relaxations of the AC optimal power flow (OPF) have recently attained significant interest as in several test cases they provably yield the global optimum to the original non-convex problem. If the relaxation is inexact, i.e. it is infeasible to the original non-convex problem, it is observed that the optimality gap is often small, and the obtained solution is close to feasibility. We propose a method based on sequential quadratic programming to recover a locally optimal solution from the solution of the inexact convex relaxation and show the benefits compared to penalization techniques. We evaluate the applicability of our method for security and chance constrained AC-OPF formulations.

#### 2 - Solving Large-scale Unit Commitment with Asynchronous Parallel Decomposition

Anthony Papavasiliou, CORE, UCL, Voie du Roman Pays 34, L1.03.01, Office b.114, Louvain la Neuve, 1348, Belgium

We present an asynchronous algorithm for solving a large-scale unit commitment problem. Dual iterations are performed using a block-coordinate subgradient method that works with delayed information, while primal solutions are recovered from the solutions of scenario subproblems using heuristics. We implement the algorithm in a high performance computing cluster and we conduct numerical experiments for instances of the Western Electricity Coordinating Council system and of the Central Western European system. The algorithm solves all instances within operationally acceptable tolerances and time limits.

#### 3 - Mobilizing Grid Flexibility for Renewables Integration through Topology Control and Dynamic Line Ratings

Shmuel S. Oren, University of California-Berkeley, Etcheverry Hall, Room 4119, Berkeley, CA, 94720-1777, United States, Jiaying Shi

We propose an optimization model that mobilizes the inherent flexibility in the transmission grid through topology control and dynamic line ratings. We determine, in a stochastic unit commitment framework, when and which lines should be switched off or adopt temporarily higher ratings as part of the recourse actions. Such recourse actions in the second stage help mitigate the adverse impact of renewable resources uncertainty and enable less conservative first stage commitments. The potential gains are demonstrated for the IEEE 118 bus test case and a more realistic test system representing the central European grid.

#### 4 - Mobilizing Renewable Resources for Power System Restoration

Georgios Patsakis, University of California Berkeley, 1460 Cedar St, Berkeley, CA, 94702, United States, Deepak Rajan, Ignacio Aravena, Shmuel S. Oren

Renewable energy currently serves a significant proportion of the electricity demand in the US. However, power system restoration is still considered predominantly a task for conventional generation, due to the intermittent nature



of many renewables and the lack of provision for algorithms that would ensure a successful operation of the renewable plants during extreme conditions. We explore the technical capabilities of hybrid (renewable and storage) units to be used as Black Start resources. We develop an optimization-based model that will recommend such systems to maximize system resilience. We illustrate our approach in a number of test power systems.

## ■ TC45

North Bldg 228A

### Frontiers on Combined Cycle Modeling for Electric Market Clearing

Sponsored: Energy, Natural Res & the Environment/Electricity  
Sponsored Session

Chair: Yongpei Guan, University of Florida, Gainesville, FL, 32611, United States

Co-Chair: Yonghong Chen, Midwest ISO, Midwest ISO, Carmel, IN, 46032, United States

#### 1 - A Tight Configuration-component Based Hybrid Model for Combined-cycle Units in Miso Day-ahead Market

Lei Wu, Clarkson University, 8 Clarkson Avenue, P.O. Box 5720, Potsdam, NY, 13676, United States

#### 2 - Frontiers on Combined Cycle Modeling for Electric Market Clearing

Yonghong Chen, Midwest ISO, 720 City Center Drive, Carmel, IN, 46032, United States

Combined cycle Modeling represents one of the most complicated resource Modeling in the electricity market clearing process. This panel discusses current advances in the modeling and solution approaches for systems with large number of combined cycles.

#### Panelists

Yongpei Guan, University of Florida, 303 Weil Hall, P.O. Box 116595, Gainesville, FL, 32611, United States

Jim Ostrowski, University of Tennessee, 11421 Old Colony Pkwy, Knoxville, TN, 37934, United States

Bowen Hua, University of Texas at Austin, Austin, TX, United States

## ■ TC46

North Bldg 228B

### Grid Modernization Lab Consortium

Sponsored: Energy, Natural Res & the Environment/Energy  
Sponsored Session

Chair: Feng Qiu, Argonne National Laboratory, Lemont, IL, 60439, United States

Co-Chair: Clayton Barrows, NREL, Golden, CO, 80401, United States

#### 1 - Energy Storage Siting And Sizing for Economic Power Dispatch Considering Battery Degradation

Liu Su, University of South Florida, ENG 302, Tampa, FL, 33620, United States, Kibaek Kim, Audun Botterud, Changhyun Kwon

Energy storage can alleviate the uncertainty of energy resources, provide flexible power system scheduling and reduce the costs of energy generation for power grids. We propose a long-term planning model for siting and sizing of energy storage under the consideration of battery degradation and formulate it as a mixed-integer programming (MIP) problem. To solve the large-scale MIP, we implement the temporal decomposition in the parallel decomposition framework. We will present the computational results on Reliability Test System - Grid Modernization Lab Consortium.

#### 2 - Scalable Capacity Expansion for Explicit Representation of Intermittent Generation

Devon Sigler, National Renewable Energy Laboratory, Golden, CO, United States, Gord Stephen, Bethany Frew, Wesley Jones

Capacity expansion models inform power system infrastructure planning decisions so future electrical power demand on the grid is met economically and reliably. With a growing amount of intermittent renewable energy being used on the grid, the number of operational scenarios that must be considered to meet these goals is growing. Historically, the number of operational scenarios considered has been limited due to the resulting increase in problem complexity from doing so. We present a scalable capacity expansion model which uses progressive hedging to solve the model via parallel computing. Planning decisions computed considering a large number of operation scenarios are presented.

#### 3 - Improving the Fidelity of Large Electric System Production Cost Models

Clayton Barrows, NREL, 15013 Denver West Parkway, Golden, CO, 80401, United States

The evolution of electrical power systems is driven by analysis using power system planning and design software tools. Many of these tools involve production cost models for optimizing scheduling decisions. This presentation highlights a suite of four interrelated Grid Modernization Laboratory Consortium projects that involve improving the fidelity and computational efficiency of production cost models, and using those improvements to gain insights into infrastructure plans and market design.

#### 4 - Warm Starting for Security Constrained Deterministic Unit Commitment

Suresh Bolusani, Lehigh University, 200 West Packer Avenue, Bethlehem, PA, 18015, United States, Feng Qiu, Ted K. Ralphs, Audun Botterud, Kibaek Kim

The deterministic unit commitment problem is usually formulated as a mixed integer linear optimization problem and solved from scratch multiple times a day resulting in a loss of useful information from previous solution processes. This loss can be avoided by warm starting the solution process. Warm starting is a process of collecting information from the solution process of one instance and reusing this information to accelerate the solution process of a closely related instance. In this talk, we present a warm starting methodology for solving deterministic unit commitment problem with transmission line constraints. We also present our computational results with an open-source implementation.

## ■ TC47

North Bldg 229A

### Bayesian Optimization

Emerging Topic Session

Chair: Amy R. Ward, University of Southern California, Marshall School of Business, Bridge Hall BRI 401H, Los Angeles, CA, 90089-0809, United States

#### 1 - Bayesian Optimization

Peter Frazier, Cornell University, School of Operations Research, and Information Engineering, Ithaca, NY, 14853, United States

Bayesian optimization is widely used for tuning deep neural networks and optimizing other black-box objective functions that take a long time to evaluate. In this tutorial, we describe how Bayesian optimization works, including the Bayesian machine learning model it uses to model the objective function, Gaussian process regression, and three common acquisition functions: expected improvement, entropy search, and knowledge gradient. We then describe applications at Yelp and Uber, explain techniques important for making it work well in practice, and survey techniques for solving "exotic" Bayesian optimization problems.

## ■ TC48

North Bldg 229B

### Sustainability

Sponsored: Energy, Natural Res & the Environment Environment & Sustainability

Sponsored Session

Chair: Gulver Karamemis, University of Rhode Island, Kingston, RI, 02881, United States

#### 1 - Modeling Economic Impacts of Climate Change Induced Weather Events to Natural Gas Sector in California

Duan Zhang, University of California, Santa Cruz, CA, 95062, United States, Yihsu Chen

We studied the regional economic impacts of weather events such as sea level rise and wildfire with a focus on natural gas sector. A computable general equilibrium (CGE) model with bilateral trade flow was constructed. The model integrates county-level details for California and state-level data for the rest of US. We used IMPLAN data to acquire social account matrices that characterize different sectors and regions. Several cases were simulated to represent impacts of sea level rise on downstream consumption of natural gas and impacts of wildfire on upstream supply.

#### 2 - Manufacturers' Competition and Cooperation in Sustainability: Stable Recycling Alliances

Fang Tian, Pepperdine University, 2720 Kensington Ave, Thousand Oaks, CA, 91362, United States, Greys Sosic, Laurens G. Debo

We study the stability of producers' strategies emerging under Extended Producer Responsibility. In our paper, the producers compete with multiple, differentiated products in consumer markets, but may consider cooperating when recycling

those products to benefit from economies of scale. Products made by different producers or sold in different markets might still be considered for joint recycling. Our main question is when and whether firm-based recycling strategies or market-based recycling strategies emerge as stable outcomes. We show that with intense market competition and differentiated market sizes, producers may recycle their products on their own without cooperating with others.

### 3 - Integration of Industry 4.0 Into Supply Chain Management to Increase Value Creation Towards Sustainability

Ozden Tozanli, PhD Candidate, University of Bridgeport,  
Engineering & Technology Building, 126 Park Ave, Bridgeport, CT,  
06604, United States, Elif Kongar

Today's dynamic market environment dramatically triggers the growing demand for customized products conjointly with the expanding operational layers in value chains. To address this, companies need to realign their long-term business strategies to adopt to the vision of future-oriented technologies. With this aim, this case study discusses the utilization of Industry 4.0 in supply chain management towards sustainability in order to increase the value-adding capability of a recycling company. The proposed results aim at delivering a new perspective to the traditional value chain in terms of economically, environmentally, socially, and technologically adaptable infrastructures.

### 4 - A Balanced Scorecard-based Approach to Integrate Sustainability Into the Operational Performance: A Food Industry Case Study

Gazi Duman, University of Bridgeport, CT, United States,  
Elif Kongar

Increasing environmental and social awareness and accompanying governmental legislations are now requiring companies to integrate these two aspects into their performance evaluations. With this motivation, this study proposes a Balanced Scorecard (BSC)-based approach combining Decision-Making Trial and Evaluation Laboratory (DEMATEL) and Analytic Network Process (ANP) methodologies for performance evaluation. To demonstrate the functionality of the approach, a case study is conducted on a U.S.-based food franchise.

### 5 - Resource Conservation vs. Waste Reduction: An Investigation

Avinash Geda, University of Florida, 361B Stuzin Hall, Gainesville,  
FL, 32611, United States, Vashkar Ghosh, Gulver Karamemis,  
Asoo J. Vakharia

This research examines whether the use of recycling to promote resource conservation, also reduces landfill waste. By analyzing a two-stage (OEM-waste management firm) supply chain, conditions under which these environmental objectives are in conflict are characterized.

## ■ TC49

North Bldg 230

### Joint Session ENRE/Practice Curated: Underground Applications

Joint Session

Chair: Alexandra M. Newman, Colorado School of Mines, Golden, CO, 80401, United States

#### 1 - Production Scheduling in Underground Mine Operations Incorporating Heat Loads

Oluwaseun Babatunde Ogunmodede, Colorado School of Mines,  
7216 Winter Ridge Drive, Castle Pines, CO, 80108, United States

Mine production scheduling determines when, if ever, notional three-dimensional blocks of ore should be extracted. The accumulation of heat in the tunnels where operators are extracting ore is a major consideration when designing a ventilation system and, often, the production scheduling and ventilation decisions are not made in concert. Rather, heat limitations are largely ignored. Our model maximizes net present value subject to additional constraints on precedence, and mill and extraction capacities. The model produces more realistic schedules that could increase revenue by lowering ventilation costs for the mine—specifically, refrigeration costs influenced by fans in the mine.

#### 2 - Hybrid Design and Scheduling for Underground Mining

Peter Nesbitt, MS, Colorado School of Mines, Golden, CO, 80401,  
United States, Levente Sipeki, Alexandra M. Newman

Underground mine design is inextricably intertwined with the corresponding production schedules. For deposits that extend deep underground, the mining direction that dictates a most profitable extraction sequence at the highest vertical level may not correspond to that at the deepest level. We formulate a mixed-integer program that determines a design and corresponding production schedule by exploiting the underlying mathematical structure. Solutions yield a more realistic production profile than a traditional one, resulting in an increased quantity of gold ounces pulled forward in the schedule and, hence, higher net present value.

#### 3 - Risk Adverse Optimization for the Ultimate Pit Problem

Gianpiero Canessa, Universidad Adolfo Ibanez, 2540 Diagonal  
Las Torres, Santiago, Chile, Bernardo Kulnig Pagnoncelli,  
Eduardo Moreno

In this work we discuss different risk averse approaches for the ultimate pit problem. We consider two sources of uncertainty, ore grade and price, and analyze the solutions using different risk measures. We compare the results of our experiments using the risk neutral case as a benchmark, and discuss the advantages of incorporating risk aversion in the construction of an ultimate pit.

### 4 - Does Supply Chain Visibility Affect Operating Performance? Evidence from Conflict Minerals Disclosures

Caroline Swift, The Pennsylvania State University, University Park,  
PA, United States, V. Daniel R. Guide, Suresh Muthulingam

Firms are increasingly held accountable for their suppliers' transgressions. Consequently, firms need to develop supply chain visibility (SCV) to exercise control and mitigate risks in their supply chains. We use data from the U.S. conflict minerals disclosure legislation to assess firms' SCV. Then, we compare the operating performance and market value of firms with high SCV against those with low SCV. We find that firms with high SCV achieve higher profitability, productivity, and market valuation than comparable firms with low SCV. We find no discernible difference in sales between firms with high SCV and firms with low SCV.

## ■ TC50

North Bldg 231A

### Pricing and Revenue Management in the Real World

Sponsored: INFORMS Section on Practice (formerly CPMS)

Sponsored Session

Chair: Shuguang Ji, Revenue Analytics, Atlanta, GU, 30339,  
United States

#### 1 - Moderator - Pricing and Revenue Management in the Real World

Shuguang Justin Ji, PhD, Revenue Analytics, Inc., Atlanta, GA,  
30339, United States

#### Panelists - Pricing and Revenue Management in the Real World

Andres Iroume, Georgia Institute of Technology, 251 10th Street  
NW, # B704, Atlanta, GA, 30318, United States

Shuguang Ji, Revenue Analytics, Atlanta, GU, 30339,  
United States

## ■ TC51

North Bldg 231B

### Practice- Production & Scheduling

Contributed Session

Chair: Emre Eryigit, UMass, 336 East Hadley Road, Amherst, MA,  
01002, United States

#### 1 - Optimal Structure of Joint Inventory and Pricing Management with Dual Suppliers

Xiaoyi Feng, AMSS, Beijing, China, Yangyang Xie, Houmin Yan

We consider a joint inventory-pricing control problem for a single-product, periodic-review, dual-supplier problem. We assume stochastic supply and demand. By extending the definition of stochastically linear in mid-point to a multidimensional setting, we prove the joint concavity of the profit functions and characterize the optimal expedited order as a state-dependent almost-threshold policy. We further clarify the forms of the stochastic supply and demand functions that guarantee the antimultimodularity of profit functions. With the antimultimodular structure, we characterize the optimal regular order and list price policies as monotone with ordered changing rates.

#### 2 - Operations Research Approaches to Mitigate Ergonomic Risks in Manufacturing Systems

Olga Batta a, ISAE-Supaero, 10 av Belin, Toulouse, 31400, France,  
Alena Otto

To reduce ergonomic risks at workplaces, most companies take the workers' task assignment as given and look for introducing specialized equipment and support tools. However, such policies have limited impact in many cases. The use of operations research approaches allows incorporating ergonomics aspects in the work assignment and scheduling and shows a high potential for improving working conditions in manufacturing systems. In this talk, we review the available modelling approaches that consider ergonomics in operational planning of manufacturing systems and outline future research directions.

#### 3 - A Data-driven Approach to Test Center Scheduling

Nickolas K. Freeman, University of Alabama, 14485 Griffin St,  
Tuscaloosa, AL, 35405, United States, John Mittenenthal

In this paper, we present a data-driven approach for scheduling students at an academic testing center. In addition to describing the approach, we present results from a benchmarking experiment based on real data. The results show that the proposed scheduling method can improve the utilization of the testing center

substantially.

#### 4 - Scheduling Meter Readings for Utility Companies in Turkey

Emre Eryigit, PhD Candidate, University of Massachusetts  
Amherst, 336 East Hadley Road, Amherst, MA, 01002,  
United States, Ahmed Ghoniem

We examine a meter reading scheduling problem that impacts the quality of the power consumption forecast made by electricity distribution companies in Turkey. The problem is modeled as a 0-1 integer program with constraints related to manpower capacity and other industry restrictions. Exact and heuristic solutions are reported in our computational study for large-scale instances involving several thousand meter groups.

#### 5 - Scheduling Meter Readings for Utility Companies in Turkey

Emre Eryigit, PhD Candidate, University of Massachusetts-  
Amherst, Amherst, MA, USA, Ahmed Ghoniem

We examine a meter reading scheduling problem that impacts the quality of the power consumption forecast made by electricity distribution companies in Turkey. The problem is modeled as a 0-1 integer program with constraints related to manpower capacity and other industry restrictions. Exact and heuristic solutions are reported in our computational study for large-scale instances involving several thousand meter groups.

## TC52

North Bldg 231C

### Flash Session I

General Session

Chair: INFORMS, 5521 Research Park Drive, Suite 200, Catonsville,  
MD, 21228, United States

#### 1 - Multiple Floors Healthcare Facility Layout Problem

Ling Gai, Shanghai University, Office 432, Management Science,  
School, No. 599 Shangda Road, Shanghai, 201444

We consider a multiple attributes group decision making problem for the multi-floor healthcare facility layout problem (MHFLP). Several feasible alternatives are produced first by solving a mixed-integer programming with the objective of minimizing flow costs. These alternatives are then evaluated according to their qualitative criteria by a group of experts. Given the facts that each alternative has several qualitative attributes, and the experts have different specialties on these attributes, we propose an method to determine the proper attributes weight and the experts weight (on different attributes), if they are only partially known in advance.

#### 2 - Credit Risk Assessment for Mortgage Lending by Artificial Intelligent Underwriter

Jian-Bo Yang, Professor, Director of DCSRC, The University of  
Manchester, AMBS East Building, Booth Street East, Manchester,  
M13 9SS, United Kingdom, Swati Sachan, Dong-Ling Xu

Underwriting for offering mortgage loans consists of assessment on affordability, credit, repayment, security, etc. This enables precise estimation of risk or ability of borrower to repay the loans. Prevalent decision-making approaches adopted by most lenders follow pre-established rules and utilities historical data. This paper discusses a novel belief-rule-based AI model and a probabilistic machine learning process to mimic human underwriters' inference and decision making process for improvement of productivity and quality. A case study is provided to show its potential wide applicability.

#### 3 - Interpretable Machine Learning Algorithm via the Belief Rule Based Expert System

Dong-Ling Xu, Chair Professor in Decision Science and Systems,  
Manchester University, Alliance Manchester Business School, F37  
MBS East, Manchester, M15 6PB, United Kingdom, Jian-Bo Yang

Some most popular machine learning algorithms, such as neural network, are not interpretable. In practice, however, there is an increasing need for transparent and interpretable machine learning algorithms. Our theoretical and applied research shows that the Belief Rule Based (BRB) expert system has a powerful learning ability which is capable of approximate complex nonlinear relationship arbitrarily close. In this presentation we outline the outcomes of the theoretical research and demonstrate the learning capability and the transparent property of the BRB system using examples.

#### 4 - The Relationship between Environmental Innovation and Environmental Productivity

JiangJiang Yang, University of Science and Technology of China,  
HeFei City, Anhui province, China

Environmental innovation has been recognized as an efficient way to alleviate environmental problem. However, how environmental innovation effect environmental productivity and the whether the impact differs from various area. We used DEA approach to investigate the relationship between environmental innovation and environmental productivity.

#### 5 - Online Customer Purchase Prediction Based on Machine Learning

Cheng Chen, Huazhong University of Science and Technology,  
Wuhan, 430074, China, Xianhao Xu

Accurate prediction of online customers' purchase behavior is of great significance to the distribution and inventory management of online retailers. Machine learning algorithm is widely concerned and applied due to its high prediction ability. In this paper, we use click stream data to predict the online customer's purchase behavior by using five supervised learning algorithms in machine learning. Detailed result analysis validated the effectiveness of the proposed machine learning methods.

#### 6 - Using Consumer Behavioral Data to Optimize Self-collection Points for Online Retailers

Yaohan Shen, Huazhong University of Science and Technology,  
Luoyu Road, Wuhan, 430074, China, Xianhao Xu

We proposed a procedure to optimize self-collection points for online retailers. Our research shows an optimal way to locate self-collection points in potential points and decide the number of self-collection points to trade off consumer service level and the total logistics cost for online retailers. We first cluster customers addresses, and predict the purchasing frequencies for each period from user behavioral data. Then we propose a mathematical model to optimize the location of self-collection points, based on customers' information.

#### 7 - Vessel Movement Labeling with Machine Learning and Dashboard Implication

Burak Cankaya, Assistant Professor, Embry-Riddle Aeronautics  
University, 600 S. Clyde Morris Blvd., Daytona Beach, FL, 32114,  
United States, Berna Eren Tokgoz, Ali Dag

This presentation proposes a machine learning based automatic labeling methodology for chemical tanker activities. The proposed methodology utilizes three machine learning algorithms to classify chemical tanker activities. The findings in this study can be used by port authorities, shipping companies, vessel operators and other stakeholders for decision support with tableau dashboard.

#### 8 - Resource-constrained Routing With Deadlock Detection for Large-scale AGV System

V Jorge Leon, Texas A&M University, College Station, TX,  
77843-3367, United States, Ek Peng Chew, Loo Hay Lee

A methodology that detects deadlocks while generating AGV routings is presented. The AGV transit layout is modeled as a capacitated-resource graph and used to make vehicle assignments and path decisions while generating routings. A new connected acyclic-and-transpose graph is proposed to detect a special case of cyclic-deadlocks during routing generation. The routing procedure runs in polynomial time.

#### 9 - Exploring Dependencies Across Multiple Online Social Network Platforms

Hwang Kim, Assistant Professor, Chinese University of Hong Kong,  
11F Cheng Yu Tung Building, # 12, Room 1134, Shatin,  
Hong Kong, Vithala R. Rao

Users' interplay among these various social networking platforms implies that several sources may induce interrelationships among the platforms. To understand this, we propose an integrated visit model that accommodates networking activities across social network platforms and test the model using data from two social network gaming platforms. The model discovers a new source of dependencies that stems from communications with friends overlapping in different network platforms. The simulation study provides the managerial implications of how firms manage networks by discovering that the proportions of overlapping friends cause asymmetric spillover effects across network platforms.

#### 10 - Pricing vs Targeting in a Reward-based Crowdfunding

lei xu, Prof., Tianjin University of Technology, Tianjin, China

Abstract not available.

#### 11 - Real-time Prediction of the Optimal Configuration of an Intelligent Gate-line System Using Queueing Theory

Eric Enkele Longomo, University of Portsmouth, Yorke Street,  
Southsea, Portsmouth, PO5 4EL, United Kingdom,  
Djamila Ouelhaj, Mark Dyne

This research paper builds on existing knowledge in the field of Queueing Theory and proposes a mathematical model that considers a Discrete Event Simulation (DES) of passengers arriving or/and in the process of exiting a train station. The mathematical model is implemented in order to compute in real-time the optimal configuration of a self-reconfiguring intelligent gateline system at an actual overground or underground train station. The DES used in this paper, models the operation of the intelligent gateline as a discrete sequence of events in time. Each event is assumed to occur at a particular instant in time and marks a potential change of states - number of passengers and gateline configuration, in the system. Overhead sensors were used to record passengers' timestamps, coordinates, average speeds and arrival at the gateline in both directions of the flow in real-time. Maximising individual gate throughput and the average gateline throughput, walkways utilisation, cutting the overall passenger waiting time, safely managing passengers' flow to prevent platform overcrowding (and potential station closure), increasing station capacity, reducing queueing in both arrival and departure and relieving station staffs from manually operating the SCU (Station



Control Unit -which controls the gateline) to occupy a more customers' engaging role represent the most important outcome of this study. Using the Queueing Theory, the minimisation of the overall customers waiting times will be considered as the objective function of the optimisation model while some of the remaining key performance indicators will be placed as constraints. In order to reduce the mathematical complexity, the convexity of the mathematical model of the objective function is established. The objective function of the gateline con?guration being convex, the global optimum is found by computing the minima.

## 12 - Analysis of Economic Resiliency for Disaster Recovery

Hulya Julie Yazici, Professor of Operations & Supply Chain Management, Florida Gulf Coast University, 10501 FGCU South Blvd, Fort Myers, FL, 33957, United States, Chris Westley, Anushka Chang

This research is based on the last twenty- six years of hurricane activity at the state of Florida and the economic indicators affecting resiliency. The analysis is conducted at prior, during and post disaster years. This presentation describes the research variables, data collection and research hypotheses. At the time of the presentation, preliminary analysis results will be available and shared with the audience for their feedback. Analysis results are expected to improve disaster recovery and help businesses find sustainable solutions.

## TC53

North Bldg 232A

### Joint Session AMD/RMP: Mechanism Design, Networks, and New Markets II

Sponsored: Auction and Marketing Design

Sponsored Session

Chair: Ozan Candogan, University of Chicago, Chicago, IL, 27708, United States

#### 1 - Pricing and Optimization in Shared Vehicle Systems: An Approximation Framework

Thodoris Lykouris, PhD Candidate, Cornell University, 107 Hoy Road, Gates 336, Ithaca, NY, 14853, United States, Siddhartha Banerjee, Daniel Freund

Optimizing shared vehicle systems is more challenging compared to traditional resource allocation due to complex network externalities. In particular, pricing/rebalancing in any location affects future supply throughout the system within short timescales. Such externalities are captured by steady-state Markovian models. However, using such models to design control policies is computationally difficult since the resulting optimization problems are high-dimensional and non-convex. To this end, we develop a general approximation framework that provides the first efficient algorithms with rigorous approximation guarantees for a wide range of objective functions and controls.

#### 2 - Revenue Management on an On-demand Service Platform

Vijay Kamble, University of Illinois at Chicago, 405 N. Wabash Ave, Unit 3511, Chicago, IL, 60611, United States

I consider the optimal pricing problem faced by a worker on an on-demand service platform. Service requests arriving while the worker is busy are lost. Thus, the optimal hourly prices need to capture the hourly opportunity costs incurred by accepting jobs. Due to potential asymmetries in these costs, price discrimination across jobs may be necessary for optimality, even if the customers' preferences are identically distributed. I first establish that such price discrimination is not necessary if the customer arrival process is Poisson. I then consider the case of multiple customer classes. I present a simple procedure to compute the optimal prices in this case under standard regularity assumptions.

#### 3 - Optimal Monitoring Schedule in Dynamic Contracts

Mingliu Chen, Duke University, Durham, NC, United States, Peng Sun, Yongbo Xiao

A principal induces effort from an agent to reduce the arrival rate of a Poisson process of adverse events. The effort is costly to the agent, and unobservable to the principal, unless the principal is monitoring the agent. Monitoring ensures effort but is costly to the principal. The optimal contract involves monetary payments and monitoring sessions that depend on past arrival times. The optimal schedules of payment and monitoring demonstrate different structures depending on model parameters, and may involve monitoring for a random period of time. Overall, the optimal dynamic contracts are simple to describe, easy to compute and implement, and intuitive to explain.

#### 4 - Optimal Forecast Disclosure in Ride-sharing Platforms

Peng Shi, University of Southern California, USC Marshall School of Business, BRI 303D, 3670 Trousdale Pkwy, Los Angeles, CA, 90089, United States, Hao Sun

We study whether ride-sharing platforms such as Uber and Lyft should share their forecast of demand with drivers, if the goal is to maximize platform profit. In a stylized model, we show that the optimal forecast disclosure policy is tied to the accuracy of the forecast and the flexibility of the pricing system. When forecast is inaccurate and pricing is fixed, the platform has incentives to hide forecast from

drivers. However, as the forecast improves, the incentive to hide disappears. In the extreme case of perfect accuracy, it is always optimal to fully reveal the forecast. Full revelation is also optimal under imperfect forecasts if the platform can do forecast-contingent dynamic pricing.

## TC54

North Bldg 232B

### Behavioral Operations with Societal Impact

Sponsored: Behavioral Operations Management

Sponsored Session

Chair: Leon Valdes, University of Pittsburgh, Pittsburgh, PA, 15260, United States

#### 1 - Risk and Fairness

Paola Mallucci, University of Wisconsin, Madison, WI, United States, Jordan D. Tong, Cuiyly Emilio

Vertical negotiations often fail because firms fail to agree on how to fairly compensate the party that faces the higher risk leading to large efficiency losses. While both preferences for fairness and for risk have been studied separately in vertical negotiation, little attention has been given to their combined effect. We address this gap by solving and testing a model where suppliers decide on the price of a good. We make predictions that account for both fairness and risk aversion and test them in a set of incentive compatible experiments. We find that subjects' actions in the presence of risk cannot be explained by models in which preferences are consistent across roles and risk situations.

#### 2 - Centralized or Decentralized Transfer Prices: A Behavioral Approach for Improving Supply Chain Coordination

Sebastian Villa, University of Los Andes, Cra. Bogota, Colombia, Elena Katok

When a retail channel includes multiple retailers, transshipments can be utilized to better match supply and demand. We study transshipment decisions in a channel with one supplier and two behavioral retailers under both centralized and decentralized transfer-price settings. We find that using the theoretical price does not help to increase neither profits nor coordination. However, by setting a behavioral transfer price, subjects place ordering decisions that lead to high supply chain profits.

#### 3 - Patient Misinformation: The Costs and the Remedy

Arshya Feizi, Boston University, 595 Commonwealth Avenue, Boston, MA, 02215, United States, Anita L. Tucker, Jillian Berry Jaeker

We explore the increased healthcare costs due to patient misinformation with their caregiver and devise a screening policy to mitigate these costs. We focus on occasions when patients misinform their caregivers about their medication compliance and how this may increase their healthcare spending due to an increased risk of hospitalization. We investigate a screening mechanism that informs the caregiver about the true state of medication compliance.

#### 4 - Trying and Failing: Donor Aversion to Rejection

Kaitlin Daniels, Olin Business School, Washington University in St. Louis, Saint Louis, MO, United States, Leon Valdes

The outpouring of concern that follows a disaster often generates excess donations. Nonprofits routinely accept these donations, fearing that turning away donors would discourage them from donating again in the future. We interrogate the extent to which this fear is warranted and study the impact of this behavior on nonprofits' inventory management. We explore some of the behavioral motives for not donating again, as well as possible interventions to mitigate donor aversion to rejection.

## TC55

North Bldg 232C

### Managing Uncertainties in New Product Development and Business Process Innovations

Emerging Topic: New Product Development

Emerging Topic Session

Chair: Janne Kettunen, The George Washington University, Washington, DC, 20052, United States

#### 1 - Impact of Queue Removing Technology on Competitive Retail

Onesun Steve Yoo, University College London, School of Management, Gower Street, London, WC1E 6BT, United Kingdom, Adam Smith

We analyze the impact of physical retailers removing the consumer's need for queuing during checkout via new technologies such as Amazon Go or Mishipay. We examine value added for the retailers in a competitive retail environment and

consumers, and provide strategic implications for startups such as Mishipay.

## 2 - Multi-period New Product Development and Risk Aversion Paradox

Janne Kettunen, The George Washington University, Department of Decision Sciences, 2201 G. Street NW, Washington, DC, 20052, United States, Shivraj Kanungo

We investigate how the conventional periodic risk-averse project selection approaches perform in multi-period new product development problems, in terms of satisfying the decision makers' risk preferences. Our results show that the conventional project selection approaches can result in that the risk in attainable profit is systematically higher under the risk-averse selection approach than even under the risk-neutral selection approach. We call this phenomenon as the risk aversion paradox. We show how projects' profits can be revised to overcome this paradox.

## 3 - Incentives for Managing Emissions in the Maritime Industry

Leonardo P. Santiago, Copenhagen Business School, Department of Operations Management, Solbjerg Plads 3, Blok B. 5. sal, Frederiksberg, Denmark, Arundhati Srinivasan, Franz Buchmann

This paper explores incentives for managing emissions in the maritime industry. We develop a market-based mechanism for smart carbon reporting. One of the key features of our model is to relax the assumption of information asymmetry by taking into account blockchain technology. We explore our model to discuss current challenges for policy makers and for potential opportunities for principals (ship owners).

## 4 - Familiar or Fresh. The Effect of Typicality on the Value of Product Design

Tian Chan, Emory University's Goizueta Business School, 1300 Clifton Road, Atlanta, GA, 30322, United States

We examine how typicality—the degree to which a design is similar to other designs of the same category—affect the market value of designs. We compiled a dataset combining US design patent data and stock market reactions in the days subsequent to the design patent grant. We show that a focal design's value rises when it is typical with respect to category-members released in the near past, and falls when it is typical with respect to category-members that are concurrently on the market. Finally, we show that designs in high clockspeed industries exhibit no positive effect of typicality on value. Our results show how firms can rethink the 'familiar or fresh' conundrum to develop valuable designs.

## TC56

West Bldg 101A

### Health Care and Bandits

Sponsored: Health Applications

Sponsored Session

Chair: Lawrence M. Wein, Stanford University, Stanford, CA, 94305-5015, United States

## 1 - Mostly Exploration-free Algorithms for Contextual Bandits

Khashayar Khosravi, Stanford University, Stanford, CA, 94305, United States, Hamsa Sridhar Bastani, Mohsen Bayati

The contextual bandit literature has focused on algorithms that address the exploration-exploitation tradeoff. Exploration-free greedy algorithms are desirable in settings where exploration may be costly or unethical. We prove that, under some assumptions on the distribution of the contexts, the greedy algorithm is rate-optimal for the two-armed bandit. Also, even absent these assumptions, we show that a greedy algorithm is optimal with nonzero probability. Thus, we introduce Greedy-First, an algorithm that uses only observed contexts and rewards to decide whether to follow a greedy algorithm or to explore. Greedy-First is rate-optimal without any additional assumption.

## 2 - Precision Healthcare Using Non-stationary Bandits

Yonatan Mintz, UC Berkeley, Berkeley, CA, United States, Anil Aswani, Philip Kaminsky, Elena Flowers, Yoshimi Fukuoka

Recommendations from fitness tracking devices are often ineffective in motivating users to exercise because the recommendations are not tailored to specific individuals. In this talk, we address this by using the data and infrastructure of fitness tracking devices to personalize exercise programs for users. We develop and analyze a new multi-armed bandit model, which we call the ROGUE multi-armed bandit, to adaptively learn each participant's exercise preferences and personalize their exercise programs to increase adherence. We present both computational and theoretical results that show the efficacy of this modeling approach when compared to existing precision fitness approaches.

## 3 - The Impact of Using an Online Health Platform on Weight Management

Yingfei Wang, University of Washington, Seattle, WA, United States, Lu Yan

Overweight and obesity have raised severe social issue in the world. Many weight-loss communities are designed, aiming to provide individuals with community support and thus help with their weight management process.

However, it has been noticed that such communities suffer from high drop-out rate. Therefore, we are interested in optimizing the online healthcare platforms strategy in suggesting a more manageable and encouraging weight loss goal, in order to facilitate user's continuous participation. In order to take into account heterogeneity in need for treatment across individuals, we formulate our problem in a Bayesian contextual bandit setting.

## 4 - Best Arm Identification in Generalized Linear Bandits

Abbas Kazerouni, 2071 El Camino Real, Palo Alto, CA, 94306, United States

Many real-world problems in personalized medicine and advertisement can be formulated as best arm identification in a structured bandit. In such problems, the goal is to identify the best among a possibly infinite set of actions with the fewest number of trials. While there is a vast literature on best arm identification in Multi-Armed Bandit with independent arms, little is known about efficient exploration schemes for structured bandits with dependent arms. In this talk, we introduce an algorithm for best arm identification in generalized linear bandits and provide a bound on its sample complexity. We further illustrate the applicability of the proposed algorithm by providing simulation results.

## TC57

West Bldg 101B

### Prevailing Issues in Public Sector OR

Sponsored: Health Applications

Sponsored Session

Chair: Hrayr Y. Aprahamian, Virginia Tech, Blacksburg, VA, 24060, United States

## 1 - The Two-stage Group Testing Problem: The Exact Analytical Solution with an Application to Robust Group Testing

Hrayr Y. Aprahamian, Virginia Tech, 1145 Perry Street, Blacksburg, VA, 24060, United States, Ebru Korular Bish, Douglas R. Bish

Group testing, i.e., testing multiple subjects simultaneously with a single test, is essential for classifying a large population of subjects as positive or negative for a binary characteristic. We develop exact closed-form expressions for the two stage group testing problem, and use these results to gain novel insights on the dynamics of an optimal solution. These results enable us to exactly solve a robust formulation of the group testing problem, which, prior to our findings, was intractable to solve. We demonstrate the value of robust testing schemes with a case study on public health screening.

## 2 - An Inventory Policy Model for Intravenous Fluids

Sasan Khorasani, Texas Tech University, Texas, Lubbock, TX, 79415, United States, Milton Louis Smith, Jennifer Cross

Intravenous fluids (IV) waste is a major source of inpatient pharmacy cost related to medication waste. Moreover, few works have been conducted on inventory policy specifically for IV medications. The optimal inventory policy for IV medications requires considering detailed parameters and variables that significantly impact waste. Thus, this study aims to observe the IV delivery process in an inpatient pharmacy, discover the main roots of IV waste for different types of medications, and establish the optimal replenishment policy for IV delivery systems.

## 3 - Online Health Communities and Health Literacy

Sejun Park, University of Texas at Dallas, 800 W. Campbell Rd, Richardson, TX 75080, Richardson, TX, 75080, United States, Taewoo Roh, Giyeon Kwag

Knowledge sharing via online health communities has been considered as a major method of communication to fortify user health literacy. These connections improve patient access to extensive healthcare information. This research investigates the impact of knowledge sharing on patient health literacy based on the activities of users in the online health community. This study outlines whether users who are not literate in medical terminology benefit from these knowledge communities and expands on the dynamics of these virtual interactions.

## 4 - Optimal Resource Allocation for Surveillance of Emerging Infections

Ngoc Nguyen, Virginia Tech, 1145 Perry Street, 214 Durham Hall, Blacksburg, VA, 24060, United States, Ebru Korular Bish, Douglas R. Bish

Accurate prevalence estimation is essential for planning of healthcare services, especially for emerging infections such as Zika. Therefore, policy-makers need to allocate the scarce resources among the surveillance activities of different infections or regions in the most efficient way. Towards this end, we develop stochastic optimization models and determine structural properties of their optimal solutions. Our case study on surveillance efforts for Zika highlights the benefits of optimization-based approaches to this decision. We also establish guidelines on effective testing strategies for surveillance of emerging infections.

## ■ TC58

West Bldg 101C

### Modeling and Optimization in Organ Allocation

Sponsored: Health Applications

Sponsored Session

Chair: Murat Kurt, Bristol-Myers Squibb, 3401 Princeton Pike, Lawrence Township, NJ, 08648, United States

#### 1 - Developing an Organ Allocation Design using Distributional Robustness

Sanjay Mehrotra, Northwestern University, Dept of I. E. / M. S. C246 Tech Inst, 2145 Sheridan Road, Evanston, IL, 60208-3119, United States, Vikram Kilamb, UT Dallas, Dallas, TX, Kevin Bui

We will present a distributionally robust model for designing an organ allocation mechanism to achieve equitable sharing of deceased donor organs. The model will be tested using data from liver allocation, using historical supply-demand information as nominal distribution. Parametric sensitivity analysis using the distributional robust modeling will provide information on the stability of the design.

#### 2 - A Sub-distribution Hazard Model to Predict the Likelihood of Deceased Donor Renal Transplant Under New Kidney Allocation System

Yeongin Kim,, Mehmet Ayvaci, Bekir Tanriover

As the rules for kidney allocation have changed recently, it is inevitable to develop a new model to predict time-to-transplant. We study adult waitlisted kidney patients in the USA after the implementation of the new Kidney Allocation Systems (KAS) using the national registry of kidney patients employing for sub-distribution hazard regression. The sub-distribution hazard regression prediction on waitlist outcomes in the KAS era carries clinically relevant information. Preparation of a risk calculator based on this model is feasible and would be a useful online tool for transplant health care providers to counsel kidney transplant candidates.

#### 3 - Head of Line Matching Policies for Allocation of Deceased Donor Kidneys

Yichuan Ding, University of British Columbia, 2053 Main Mall, Vancouver, BC, V6T1Z2, Canada, Baris Ata, Stefanos Zenios

We seek the deceased-donor kidney allocation policy that achieves the best efficiency-equity tradeoff, taking into account patients' strategic choices. We developed an analytical framework based on the fluid model that can analyze a broad class of ranking policies, which provides approximations to the previously and currently used policies in practice. The analysis characterizes the optimal scoring formula for given efficiency-fairness tradeoffs. Our results show that the policies that incorporate characteristics of both the donor and the recipient can improve the quality-adjusted-life-years up to \$3.1\%\$ based on the fluid model predictions, and also eliminates kidney wastage.

#### 4 - Effective Adult Heart Allocation Policies: An Optimization Approach

Fatemeh Karami, University of Louisville, JB Speed Bldg. 211, e, Louisville, KY, United States, Mehdi Nayeypour, Monica Gentili, Naoru Koizumi, Andrew Rivard

Heart failure is a growing health problem affecting nearly 6 million in the United States, with approximately 200,000 patients suffering from a progressed to end-stage or Stage D heart disease. Heart transplantation is the definitive therapy for the end-stage heart disease patients. However, the geographic disparity in access to heart transplant in the United States is substantial. This research analyzes the geographic disparity in the heart allocation system and explores different heart allocation boundaries derived from our mathematical optimization models to decrease disparity.

## ■ TC59

West Bldg 102A

### Aged Care Analytics: Models, Methods and Applications: Part II

Sponsored: Health Applications

Sponsored Session

Chair: Nan Kong, Purdue University, West Lafayette, IN, 47906-2032, United States

Co-Chair: Mingyang Li, Tampa, FL, 33647, United States

#### 1 - Heterogeneity Modeling of Drug Use Behavior via Semi Markov Mixture Modeling

Zhouyang Lou, Purdue University, West Lafayette, IN, 47906, United States, Nan Kong, Christopher Callahan, Wanzhu Tu, Noll Campbell, Qing Tang

Drug use disorder harms individual health as well as the welfare of others.

Modeling of behavior are essential to early detection of drug abuse and optimization of behavioral interventions from clinicians and pharmacists. A longitudinal drug dispensing dataset is used to study drug use behavior. We develop a semi-Markov mixture modeling approach to model heterogeneous drug use behavior. We identify a weighted combination of canonical semi-Markov models for each individual. We use the frailty term embedded in the semi-Markov models to characterize the heterogeneity among individual behaviors.

#### 2 - A Multi-attribute Optimization Approach for Post Acute Care System Management

Hossein Badri, Wayne State University, Detroit, MI, United States, Ashkan Hassani, Maryam Khatami, Mark Lawley, Kai Yang

In this study, a stochastic multi-attribute decision making approach is developed for the Post Acute Care System (PACS) management. In this problem, besides the cost metrics, there are some service coverage requirements that make the decision making complex. The proposed approach provides the decision making procedure for healthcare providers who are willing to subcontract post-acute care services. The proposed approach is implemented for PACS management problem in the city of Houston, TX.

#### 3 - Using Analytics to Understand and Model the Problems of Seniors Blocking Hospital Beds

Michael Carter, ON, Canada, Pavel Shmatnik

The aging demographic created by the "Baby Boomers" is creating some serious capacity issues for downstream sub-acute facilities like nursing homes, retirement homes, rehab and home and community services. The problem is bound to get worse over the next 10-20 years. Today, over 16% of hospital beds are occupied by someone who is supposed to be somewhere else. This is a fairly common problem internationally and Health Authorities are scrambling for intelligent solutions that do not simply involve more money. In this paper, we will present some of our preliminary analysis on root causes and modelling alternatives.

#### 4 - Midterm Nurse Scheduling with Specialized Constraints and Preference Considerations

Jia Guo, PhD Student, The University of Texas at Austin, Austin, TX, 78731, United States, Jonathan F. Bard

A nurse scheduling IP model is developed to minimize the sum of weighted unsatisfied demand and individual preference violations. Constraints account for vacations, birthdays, maximum number of consecutive working days and days off, and minimum number of rest hours. The problem is solved in two phases using a column generation algorithm. In the first phase, overtime is not allowed. In the second phase, we take the first phase solution and add overtime to cover unsatisfied demand. Results are presented for instances with up to 30 nurses.

## ■ TC60

West Bldg 102B

### Health Applications

Sponsored: Health Applications

Sponsored Session

Chair: Bryan A. Norman, Texas Tech University, Lubbock, TX, 79409-3061, United States

#### 1 - Creating a Robust Hospital Pharmacy Delivery System

Anna Svirska, University of Pittsburgh, 4200 Fifth Avenue, Pittsburgh, PA, 15260, United States, Hamdy Salman, Bryan A. Norman

Large hospital systems route medications from the hospital pharmacy to the inpatient units daily. The medication demand on each unit varies based on the patients in the unit and their medical conditions. First, we create a linear program to establish delivery pathways and then formulate the robust counterpart. Using historic data, we consider the deterministic problem where our unit demand is the average medication demand compared to the robust formulation where the demand is given by an uncertainty set based on the medication demand across each day for a year. We compare the deterministic and robust solution to note the difference between the two formulations.

#### 2 - Social Platforms on Healthy Eating Mobile App: Who Participate in What Activities, and Why Not?

Yi-Chin Kato-Lin, PhD, Hofstra University, Hempstead, NY, 11549, United States, Rema Padman, Vibhanshu Abhishek, Julie Downs

A mobile app for healthy eating was designed for our study participants' use. Users' behaviors in interacting with peers on a closed social platform were observed. Matching the app usage data with survey data allows us to understand who participate in what activities, or why they were not participating.



### 3 - A Chance Constrained Model to Locate an Automated Central Fill for a Community Pharmacy Network

Hamdy Salman, 1989, Pittsburgh, PA, 15216, United States, Wei Wang, Bo Zeng, Bryan A. Norman, Bryan A. Norman

Community pharmacies play an important role in providing patient safety by providing Pharmacist To Patient (PTP) interaction. One of the strategies to provide more PTP interactions in a community pharmacy is to use an automated Central Fill. An automated central fill offloads part of the pharmacy's prescription filling process. Our research focuses on locating a central fill that can provide relief for multiple pharmacies under stochastic demands. We provide a chance constrained capacitated facility location model when pharmacy demands are variable. The results include a comparison between using a chance constraint model and using a simpler policy to determine the central fill location.

### 4 - Sequential Modeling and Optimization for Resources in Mail-order Pharmacy Automation Systems

Duaa Serhan, Binghamton University, 4400 VESTAL PKWY E, Binghamton, NY, United States, Sang Won Yoon, Husam Daoud

This research proposes an integrated optimization strategy to improve resource planning and replenishment operations in Central Fill Pharmacies (CFPs). The objective of this research is to develop a resource planning solution that determines the number of required dispensers, canisters, and replenishment operators. An integer programming mathematical model is developed to solve the planogram design and replenishment planning problems simultaneously. Tabu Search and Genetic Algorithm are proposed to solve this NP-hard problem efficiently. This research is expected to help with understanding the factors that influence CFP resource planning.

## ■ TC61

West Bldg 102C

### Optimization Society Award II

Sponsored: Optimization

Sponsored Session

Chair: David Morton, Northwestern University, IEMS Department, 2145 Sheridan Road, Evanston, IL, 60208, United States

#### 1 - Learning Semidefinite Regularizers from Data

Yong Sheng Soh, California Institute of Technology, Pasadena, CA, United States

Regularization functions are widely used in optimization-based approaches for solving ill-posed inverse problems. These serve to induce desired structure in solutions, and are typically chosen based on domain-specific expertise. We consider the problem of learning regularizers from data in settings in which domain knowledge is not available. The regularizers we obtain are convex functions that can be computed via semidefinite programming. Our approach is based on computing certain structured factorizations of data matrices, and it requires the Operator Sinkhorn iteration as a subroutine.

#### 2 - Pareto Efficiency in Robust Optimization

Nikos Trichakis, MIT, Cambridge, MA, United States, Dan Andrei Iancu

We formalize the concept of Pareto efficiency in the context of robust optimization (RO) for linear optimization. We argue that RO need not produce solutions that are Pareto robustly optimal (PRO), and illustrate how this could lead to suboptimal performance. We provide a theoretical characterization of PRO and show how to verify and generate PRO solutions by solving optimization problems of the same complexity as the underlying RO problems; hence, the potential improvements from PRO come at no extra computational cost. Numerical studies demonstrate PRO solutions to have significant upside.

#### 3 - On the Construction of Converging Hierarchies for Polynomial Optimization Based on Certificates of Global Positivity

Amir Ali Ahmadi, Princeton University, Dept. of Operations Research & Financial Eng., Sherrerd Hall (room 329), Charlton Street, Princeton, NJ, 08544, United States, Georgina Hall

In recent years, techniques that combine semidefinite programming with Positivstellensatz from algebraic geometry to produce a converging hierarchy of lower bounds for polynomial optimization problems have gained much popularity. In this talk, we show that such hierarchies can in fact be designed from much more classical statements in algebra dating back to the 1920s. We also provide a converging hierarchy of lower bounds for polynomial optimization problems which does not require optimization at all, but simply the ability to multiply polynomials together.

### 4 - Optimization Society Award

David Morton, Northwestern University, IEMS Department, 2145 Sheridan Road, Evanston, IL, 60208, United States

Winners of the following Optimization Society Prizes will present their work: Student Paper Prize; Young Researchers Prize; and Farkas Prize.

## ■ TC62

West Bldg 103A

### Joint Session DM/Practice Curated: Optimization in Data Mining and Analytics

Sponsored: Data Mining

Sponsored Session

Chair: Young Woong Park, Iowa State University, Ames, IA, 50011, United States

#### 1 - A Mathematical Programming Approach for Imputation of Unknown Journal Ratings in a Combined Journal Quality List

Young Woong Park, Iowa State University, 2167 Union Drive, 2139 Gerding Business Building, Ames, IA, 50011, United States, Jinhak Kim, Alvin Williams

Many journal quality lists rate limited numbers of journals. However, in many academic institutions, fair evaluation procedure is needed to rate journals that are not listed in their trusted journal quality lists. In this research, mathematical programming models are proposed to determine unknown ratings of multiple journal quality lists only using their known rating information. The objective of the models is to minimize the total number of instances where two journals are rated in opposite order by two quality lists. Computational results based on the journal quality list data in <https://harzing.com> show that our method outperforms existing multiple imputation algorithms.

#### 2 - Recent Advances in Mixed-integer Optimization Approaches to Feature Subset Selection

Yuichi Takano, University of Tsukuba, Tsukuba-shi, Japan, Ryuhei Miyashiro

Mixed-integer optimization (MIO) approach to feature subset selection was proposed in the 1970s, and recently it has received renewed attention due to progress in algorithms and hardware. In this talk, I review some recent advances in MIO approaches to feature subset selection and introduce latest research developments of our group.

#### 3 - Optimal Clustering on a Graph

GOKCE Kahvecioglu, Northwestern University, 2145 Sheridan Road, Room C210, Evanston, IL, 60208, United States, David Morton

We study a hierarchical clustering problem on an undirected graph with a weight function assigning nonnegative weights to the edges. We remove a subset of edges to break the graph into a number of smaller pieces, i.e., clusters. We consider a bicriteria graph clustering problem, in which we maximize the number of clusters while minimizing the weight of deleted edges. Solving this bicriteria problem parametrically identifies solutions that lie on the concave envelope of the efficient frontier, and the breakpoints on this envelope are nested, yielding a hierarchical family of clusters. We illustrate our ideas using NCAA football schedules, attempting to identify conferences, divisions, etc.

#### 4 - Mixture-based Multiple Imputation Models for Clinical Data with a Temporal Dimension

Ye Xue, Northwestern University, Evanston, IL, United States, Yuan Luo, Diego Klabjan

Missing values are commonly occurred in many kinds of datasets, especially in time series. We present mixture-based multiple imputation models for multivariate time series. We design mixture models with one component capturing the correlation between variables and others catching the fluctuations of time series. The mixture models are optimized by maximizing their mixture likelihood functions using Estimation and Maximization (EM) algorithm. Then the imputation is performed based on the estimates of parameters of the optimized mixture models. We demonstrate the effectiveness of our imputation models on clinical data with a temporal dimension.

## ■ TC63

West Bldg 103B

**Joint Session DM/Practice Curated:  
Data Science for Electrical Markets**

Sponsored: Data Mining

Sponsored Session

Chair: Mehrdad Pirnia, University of Waterloo, 200 University Ave West, Waterloo, ON, N2L3G1, Canada

**1 - Internet of Things for Power Consumption**

Rachneet Kaur, Student, University of Illinois-Urbana Champaign, Department of Industrial Engineering, TB 21, Champaign, IL, 61820, United States, Richard Sowers, Kevin Thompson

The objective of our research is to use historical pricing data from a U.S. energy supplier to schedule policies which can be implemented in a smart home which allows for a major appliance to be turned on so as to minimize cost. The policy is back tested, showing significant savings. We design a dishwasher that can be activated via voice command through the use of an app, wireless speaker (Amazon Echo Dot), and an AI voice assistant (Amazon Alexa). More importantly, we want to predict the future price of power in order to activate the dishwasher at an optimal time to save the consumer on the operation cost of the dishwasher.

**2 - Data-driven Strategies for Trading Renewable Energy Production**

Miguel A. Muñoz, PhD. Student, University of Malaga, Edificio I+D Ada Byron, Malaga, Spain, Juan Miguel Morales, Salvador Pineda

In this talk we first introduce the problem of selling renewable energy in day-ahead electricity markets with a dual-price balancing settlement as a newsvendor problem. We then analyze different strategies to include information of auxiliary variables that may have predictive power on the renewable power production. Different data-driven optimization techniques are used to determine the optimal amount of energy to be sold in the market taking into account the information of those variables. The performance of these techniques is evaluated in a realistic case study in which we consider a single renewable power producer trading the whole wind power production of a relatively small country.

**3 - A Bilevel Optimization Model for Estimating Utilities of Price-responsive Electricity Consumers**

Arnab Roy, PhD Candidate, University of Louisville, 3177 South 3rd Street, Louisville, KY, 40214, United States, Lihui Bai, Chaosheng Dong, Bo Zeng

A bilevel optimization model is presented to estimate parameters of the utility function for price-responsive electricity consumers. The lower level minimizes the sum of electricity cost and inconvenience cost, due to consumers' curtailment of load in a demand response event. Real-world data from a field demonstration project is used in a joint predictive and prescriptive model (Bertsimas and Kallus, 2015). The upper level minimizes the difference between the total consumption determined by the lower level problem and the consumption measurements from the collected data.

**4 - Chance Constrained Optimization to Model Micro-grids with Renewables and Storage Capacities**

Mehrdad Pirnia, University of Waterloo, 200 University Ave West, Waterloo, ON, N2L3G1, Canada, Hassan Shavandi, Alberto J. Lamadrid, John David Fuller

In this presentation, we develop a social welfare maximization model with storage capacities (batteries), considering wind uncertainties. The uncertainties associated with wind generation is modeled using chance constraints. Furthermore, an equivalent deterministic mixed integer programming model is used to find the solution of the chance-constrained model. We use these models to analytically investigate the impact of storage capacities on the electricity prices, and the optimal number of charge/discharge for batteries. We also present the electricity price differences between the stochastic and deterministic models.

## ■ TC64

West Bldg 104A

**Data Analytics for Behavioral Operations and Business Decisions**

Sponsored: Data Mining

Sponsored Session

Chair: Mohsen Ahmadian, University of Massachusetts Boston, Malden, MA, 02148, United States

**1 - The Impact of Sellers' Reputation on Customers' Purchasing Intention Toward Remanufactured Products**

Zhaoji Yu, Shenyang University of Technology, Shenyang, China  
Zhaoji Yu, California State University, Stanislaus, Turlock, CA, United States, Yingzi Zhao, Xun Xu

Apart from elevating public awareness of sustainable consumption, remanufacturing offers an opportunity for products to create a "secondary value". Since remanufacturing is a manufacturing process, the ultimate goal is to promote the product sales. Laying emphases on fixed-price trading environment, this paper studies the influence of remanufactured product seller's reputation on the customer's willingness to purchase a remanufactured product. The results of the study confirm that consumers are more willing to buy products from manufacturers than are remanufactured by sellers. Interestingly, we also find that the longer the seller registered, the lower its consumer willingness to buy.

**2 - Forecasting and Inventory Control with Compound Poisson Demand Using Periodic Demand Data**

Dennis Prak, University of Groningen, Nettelbosje 2, Groningen, 9747 AE, Netherlands, Ruud Teunter, Mohamed Z. Babai, Aris Syntetos, John E. Boylan

We propose a consistent, closed-form method-of-moments estimator for compound Poisson demand parameters that dominates in terms of estimation accuracy and achieved service level. It estimates the arrival rate from the fraction of periods without demand, and combines this with the average of period demand to estimate the mean demand size. It outperforms standard method-of-moments for intermittent demand patterns and performs similarly to maximum likelihood. Period forecasting techniques as implemented in software are not suitable for inventory control based on compound Poisson demand, and doing so leads to severe biases and too high inventories.

**3 - Predicting Order Variability in Inventory Decisions: A Model of Forecast Anchoring**

Dayoung Kim, Assistant Professor, California State University Fullerton, 800 N. State College Blvd, SGMH 5373, Fullerton, CA, 92831, United States, Andrew M. Davis, Li Chen

We take a unique perspective to the Newsvendor problem, by developing a simple theoretical model that can accurately predict order variability (of human subjects), in addition to average orders. Indeed, a number of behavioral models which can predict average newsvendor orders (i.e. the pull-to-center effect) have been proposed, but they cannot explain and predict order variability observed in data. Therefore, from a managerial standpoint, our model allows upstream suppliers the ability to form a complete forecast distribution of downstream orders, leading to better inventory decisions, planning, and increased profitability.

**4 - Multi-product Demand Prediction and Price Optimization**

Yasaman Shahi, PhD Student, Georgia Institute of Technology, 755 Ferst Dr, Atlanta, GA, 30318, United States, Kris Johnson Ferreira, Gurhan Kok

Multi-product demand prediction models typically lack either flexibility or interpretability. We propose a neural network architecture that balances these two and show how it can be used in price optimization. We partner with a consumer electronics retailer to estimate our demand model and implement our price optimization approach.

**5 - Rival Chasing Behavior in Simultaneous Competitions**

Mohsen Ahmadian, PhD Student, University of Massachusetts Boston, 100 William T. Morrissey Blvd., College of Management, Boston, MA, 02125, United States, Roger H. Blake, Ehsan Elahi

This research uses the results of laboratory experiments in which subjects playing the role of suppliers competing for the business of a buyer. These results show significant differences with predictions from theory. We find the observed behaviors can be explained by a phenomenon that we name "rival-chasing". Rival-chasing is individuals' tendency to change their decisions toward their competitors' decisions. In symmetric competitions, this tendency leads to a faster convergence of the decisions. However, in asymmetric competitions, rival-chasing behavior results in a closer gap between observed decisions compared with the gap between the equilibrium points predicted by the theory.

## ■ TC65

West Bldg 104B

### Data Science and Deep Learning II

Sponsored: Data Mining

Sponsored Session

Chair: James Patrick Bailey, Georgia Institute of Technology, Atlanta, GA, 30309, United States

#### 1 - Relaxed Wasserstein and Applications to Generative Adversarial Networks

Tianyi Lin, University of California, Berkeley, 4174 Etcheverry Hall, 2521 Hearst Ave, Berkeley, CA, 94709, United States, Xin Guo, Johnny Hong, Nan Yang

We propose a class of statistical divergences called \textit{Relaxed Wasserstein} (RW) divergence. We establish for RW divergence several properties: 1) RW divergence is dominated by Total Variation and Wasserstein- $L^2$  divergence; 2) RW divergence has continuity, differentiability and duality representation; 3) RW divergence has a non-asymptotic moment estimate and a concentration inequality. Experiments on the image generation demonstrate that RWGANs possess better convergence than the existing WGANs with competitive inception scores. To the best of our knowledge, this is the first to provide both the flexibility to design effective GANs and the possibility to study different losses.

#### 2 - Probabilistic Mixture Models for Predicting Unbalanced Thunderstorm-induced Power Outages

Elnaz Kabir, University of Michigan, 1205 Beal Ave., Ann Arbor, MI, 48109, United States, Seth Guikema, Steven Quiring

Severe storms have substantial impacts on power systems, posing risks and inconveniences due to power outages. Statistical prediction models have promise for supporting utility response, but power outage data are highly zero-inflated. In this study, we propose probabilistic mixture models for predicting the spatial distribution of power outages based on zero-inflated data. The result shows that these models offer strong predictions with zero-inflated data.

#### 3 - Multiplicative Weights Update in Zero-sum Games

James Patrick Bailey, Postdoctoral Researcher, Singapore University of Technology and Design, Singapore

We study the classic setting where two agents compete in a zero-sum game by applying Multiplicative Weights Update (MWU). In a twist of the standard approach of Freund, we show the K-L divergence from an equilibrium increases and that strategies converge to the boundary of the smallest face containing all equilibria. Our results come in stark contrast with the standard interpretation of the behavior of MWU in zero-sum games, which is typically referred to as "converging to equilibrium". If equilibria are indeed predictive even for the benchmark class of zero-sum games, agents in practice deviate robustly from the axiomatic perspective of optimization driven dynamics captured by MWU.

## ■ TC66

West Bldg 105A

### Joint Session QSR/Practice Curated: Prognostics and Health Management

Sponsored: Quality, Statistics and Reliability

Sponsored Session

Chair: Tongdan Jin, Texas State University, San Marcos, TX, 78666, United States

Co-Chair: Yan-Fu Li, Tsinghua University, Beijing, 100084, China

#### 1 - Joint Optimization of Maintenance Planning and Workforce Routing for Networked Infrastructures

Chi Zhang, Tsinghua University, Department of Industrial Engineering, Tsinghua University, Beijing, 100084, China, Chuanchou Jia

The economic development and social well-being of modern societies are highly dependent on networked infrastructures. Thus, it is necessary to timely and effectively maintain them to ensure the reliability of their continuous operation. However, their components are geographically distributed and the time required to transport between the components needs to be considered in order to make achievable maintenance plans. To address this problem, we transfer the time of each component being maintained into their sequence of being visited by each team of workforce, and propose a new approach to jointly optimize the maintenance planning and workforce routing for a networked infrastructure.

#### 2 - A New Algorithm with Real-time Smoothing for Predicting Blood Glucose Concentrations Based on Wavelet Filters

Lei Li, Beihang University, Beijing, China, Jun Yang

Based on the Continuous Glucose Monitoring (CGM) data, we aim at predicting future blood glucose levels so that appropriate actions can be taken in advance to prevent hyper/hypoglycemia. Due to the small fluctuations of CGM data, an ARMA model with a wavelet filter is proposed in the prediction framework. To verify the performance of the proposed method, we conduct the proposed method with different wavelet function, different decomposition levels and threshold methods of wavelet denoise in a case study based on the CGM data of 5 diabetics. Results show that the proposed methods with db8 wavelet function and minimaxi threshold method has most satisfactory and robust performance.

#### 3 - The Recognition Method of the Equipment State Based on the MTS Modified by FDA

Ning Wang, Chang'an University, Middle-section of Nan'er Huan Road, Xi'an, ShaanXi, 710064, China, Dawei Hu, Yingbin Fu

Mahalanobis-Taguchi System (MTS) is a kind of data classification and reduction method using Mahalanobis distance (MD) as the measurement scale to identify the system state with multidimensional characteristics. In this paper, against the imbalanced classification by the model to identify the sample when the benchmark and abnormal space constructed by the traditional MTS have a serious overlap, a modified MTS amended by Fischer linear discriminant analysis (FDA) is proposed, and to be used to recognize the running state of equipment. The result proves the effectiveness and superiority of the modified model.

#### 4 - Scheduling of Maintenance Teams and Activities for Nuclear Power Plant Subsystems

Meng-Yu Du, Tsinghua University, Beijing, China, Yan-Fu Li

The existing research works on nuclear power plant (NPP) maintenance scheduling normally assume that activities are performed on the exact scheduled times. However, due to budget limit, the shortage of maintenance workers cannot be ignored and thus the plans can be missed. To deal with this problem, we propose an integrated scheduling of maintenance teams and activities. A mixed integer program model is built with the objective of minimizing maintenance cost. The lower bound of system unavailability, limited maintenance workers, etc. are regarded as constraints. The proposed optimization model is applied to an NPP subsystem and solved by a mathematical programming solver.

## ■ TC67

West Bldg 105B

### Joint Session ISS/AI/Practice Curated: Applications of Deep Learning Methods in Information Systems

Sponsored: Information Systems

Sponsored Session

Chair: Xiao Liu, University of Utah

#### 1 - How Are You Feeling Today? Let Online Cancer Communities Help You Feel Better

Anqi Xu, University of Utah, Salt Lake City, UT, United States, Paul Hu

Cancer is devastating and has profound effects on patients' well-beings, both physical and emotional. Cancer patients need strong social support in different aspects and their emotions can greatly benefit from effective support. Toward that, online communities are crucial because they can provide the needed support to cancer patients. This study analyzes patients' different social support needs, then develops and empirically evaluates a deep learning-based, multi-label classification method to scrutinize their respect effects on a patient's emotion change, with a focus on the fit between the patient's particular need and the specific support by an online cancer community.

#### 2 - Using Crowd Reactions to Detect Social BOT Intent

Victor Benjamin, Arizona State University, Tempe, AZ, United States, Kunal Sahay, Raghu Santanam

Social bots hold immense power, as they are excellent broadcasters of good/bad messages in high velocity. Some bots are useful because they can assist other users in several ways, such as providing news article summaries. However, other bots act maliciously by spreading misinformation or exploiting users. As these bots become more prevalent on social media, platform owners must identify strategies to manage them. One key capability that platforms need is the ability to distinguish between beneficial and harmful social bots that exist within their platform. In this research, crowd reactions to known social bots are scrutinized through a deep learning framework to assess the intent of the bot.



### 3 - Go to YouTube and See Me Tomorrow: The Role of Social Media in Managing Chronic Conditions

Xiao Liu, University of Utah, Salt lake City, UT, United States,  
Bin Zhang, Anjana Susarla, Rema Padman

To assess the medical knowledge in YouTube videos, we propose an interdisciplinary lens that synthesizes deep learning methods with themes emphasized in Information Systems (IS) research and research on healthcare informatics. We extract medical terminology from videos. We annotate videos using inputs from domain experts and build a logistic regression based classifier to categorize videos based on whether they encode a high degree of medical knowledge or not. We find that medical terminology embedded in textual data is more salient to an assessment of medical knowledge encoded in a video, rather than image analytics.

### 4 - Predicting Hepatocellular Carcinoma Recurrences: A Data-Driven Multiclass Classification Method by Incorporating Hidden Risk Factors

Qihua Sheng, University of Utah, Salt Lake City, UT, 84102,  
United States, Da Xu, Paul Hu, Tingshuo Huang, Wen-Chen Lee

Hepatocellular carcinoma (HCC), a malignant disease, is normally treated with surgical resections that however often associated with high cancer recurrence rates. We propose a Bayesian network-based method to infer HCC recurrences by incorporating distinctive pathogenesis that differs between early and late recurrences. The proposed method considers the underlying mechanisms control the clinical endpoint in the learning process and offers interpretability and flexibility to support HCC prognosis predictions.

## TC68

West Bldg 105C

### Joint Session QSR/DM: Developments in Additive Manufacturing Systems

Sponsored: Quality, Statistics and Reliability

Sponsored Session

Chair: Arman Sabbaghi, Purdue University, West Lafayette, IN, 47907, United States

#### 1 - An Adaptive Data Augmentation Strategy for Fitting Gaussian Process Models with Application to 3D Printing

Tirthankar Dasgupta, Rutgers University, Minge Xie

Gaussian process (GP) models are useful tools for fitting models that predict in-plane deformation of 3D-printed products. However, products are often produced sequentially (either individually or in batches), making it necessary to develop computational procedures that allow sequential augmentation of data obtained from manufactured products. We propose a novel approach for adaptive estimation of GP model parameters using an inferential tool called confidence distribution (CD) that also helps capture the uncertainty associated with the estimators. The method can also help reduce the computational burden associated with GP modeling using the “divide and conquer strategy.”

#### 2 - Data and Compute Challenges in Enabling 3D Printing for Mass Customization

Jun Zeng, HP Labs, HP Inc., 1501 Page Mill Road, Palo Alto, CA, United States

Industry 4.0 will disrupt the 12 Trillion-dollar manufacturing business by enabling producing customized products with mass manufacturing cost efficiency. 3D printing holds the promise to realize this Industry 4.0 vision however there are multiple technology challenges from design to production covering a broad spectrum of hardware, software and material sciences. This paper will describe generative design thinking (aka. design-for-additive manufacturing), interoperability and file formats (e.g., 3MF), high-fidelity manufacturing including process, sensing, and data-driven compensation and control drawing from our learning from commercializing HP's Multi Jet Fusion technology.

#### 3 - Understanding the Requisite Ecosystem to Qualify Aerospace Additive Manufactured Parts

William Bihlman, Aerolytics LLC, West Lafayette, IN, United States

Additive manufacturing (AM) shows promise to be highly disruptive in many industrial markets. Aerospace, however, lags. This presentation will address the primary challenges that are rather unique to commercial aerospace. It explores questions such as: Why is aerospace slow to adopting this technology? What are the main targets/components? How does this differ between engine vs airframe markets? In short, it will discuss the requisite ecosystem to necessitate adoption of AM for one of society's highest risk-adverse industries. Indeed, AM is a powerful new paradigm. But is aerospace able to engage?

#### 4 - A Data Fusion Framework for Historical and Prototype Experimental Data with Applications to Personalized Heart Surgery Planning and Optimization

Chuck Zhang, Georgia Institute of Technology, Atlanta, GA, United States, Jialei Chen, Kan Wang, Simon Mak, Roshen Vengazhiyl, Ben Wang

This paper presents a study of augmenting historical patient data with experimental data based on 3D printed patient prototypes to develop more reliable predictive models for physicians and surgeons to use to make more informed decisions for surgery planning and optimization. This research work involves innovative materials design for creating tissue-mimicking structures, multi-material 3D printing, machine learning for generating “virtual patients, and data fusion. This method is demonstrated through an application case of outcome prediction of transcatheter aortic valve replacement (TAVR) surgery.

## TC69

West Bldg 106A

### Joint Session QSR/Practice Curated: Reliability and Quality for Industry Applications

Sponsored: Quality, Statistics and Reliability

Sponsored Session

Chair: Zhimin Xi, University of Tennessee - Knoxville, 851 Neyland Dr, 517 JDT, Knoxville, TN, 37996, United States

#### 1 - Lithium-ion Battery Pack SOC Estimation Considering Cell-to-Cell Variability

Modjtaba Dahmardeh, Rutgers, The State University of New Jersey, Piscataway, NJ, United States, Zhimin Xi

Accurate estimation of lithium-ion battery pack SOC is technically challenging because of the cell-to-cell variability caused by the manufacturing tolerance. In addition, there is no unanimous definition of the pack SOC since each cell has its own SOC and the pack can be configured in different ways. This study firstly investigates different pack SOC definitions and adopts the one best suitable in our study. Next, uncertainty modeling and propagation analysis are conducted for accurate pack SOC estimations considering the cell-to-cell variability. Both analytical and simulation solutions are reported under different scenarios.

#### 2 - A New Collision Avoidance Algorithm for Autonomous Vehicles Based on the Velocity Obstacle Algorithm

Elnaz Torkamani, Rutgers, The State University of New Jersey, Piscataway, NJ, United States, Zhimin Xi

Vehicle navigation autonomously in a dynamic environment is a challenging task because it should not be pre-programmed under a given handful situations and the vehicle must be able to avoid collisions under numerous unforeseeable but reasonable situations to a human being. From the practical perspective in autonomous cars, the algorithm must be efficient and reliable. This study proposes a new vehicle collision avoidance algorithm for multiple obstacles by eliminating the need of running sampling or optimization approaches, so that the algorithm could be practical useful in real-time collision avoidance under high vehicle speed.

#### 3 - Reliability-Based Optimal Design of a Micro-Grid System under Natural Disasters

Zhetao Chen, Rutgers, The State University of New Jersey, Piscataway, NJ, United States, Zhimin Xi

This study proposes reliability-based optimal design of a micro-grid system under service disruptions due to natural disasters. The objective is to determine the minimum number of generators and their distributions in the micro-grid so that the system's recoverability can be guaranteed under random failure scenarios of the power transmission lines. Power flow analysis combining with the Monte Carlo simulation (MCS) are used for uncertainty propagation analysis to quantify the system's recoverability distribution under random failure scenarios of the transmission lines. The proposed work is demonstrated through a 12-bus power system.

#### 4 - Finite Element Modeling of the Selective Laser Melting Process for Ti-6Al-4V

Alaa Olleak, Rutgers, The State University of New Jersey, Piscataway, NJ, United States, Zhimin Xi

Physics-based modeling of the selective laser melting (SLM) process is critical for better understanding the influence of the parts quality with respect to various process parameters and scanning strategies. The challenge is to balance model validity, domain size, and computational efficiency so that the model can be practically useful for improving reliability and quality of the printed products. In this study, a transient thermal finite element model of a SLM process for Ti-6Al-4V is developed using ANSYS for predicting the melt pool size and its temperature history. The thermal model is then integrated with mechanics-based modeling process for predicting the residual stress of the products.

### 5 - Deep Autoencoder with Regularization on Sensor Signals for Virtual Metrology in Semiconductor Manufacturing

Jeongsub Choi, Rutgers University, 96 Frelinghuysen Road, Core Building, Room 201, Piscataway, NJ, 08854, United States, Harshit Bokadia, Myong K. Jeong

In semiconductor manufacturing, feature extraction from raw sensor signals on process equipment is an essential task to build an accurate predictive model for virtual metrology. Autoencoder is a neural network based feature extraction model that compress inputs into features in a latent space. In this talk, we present a new virtual metrology method with a new regularized deep autoencoder considering the characteristics of sensory data. Experimental results with real-life data show that the proposed method improves the performance of prediction models for virtual metrology.

## ■ TC70

West Bldg 106B

### Highly Reliable Complex System Modelling and Analysis

Sponsored: Quality, Statistics and Reliability

Sponsored Session

Chair: Dan Yu

Co- Chair: Qingpei Hu

Co- Chair: Yimin Zhou

#### 1 - Accelerated Degradation Testing Modelling and Analysis with Recovery Capability Considered

Qingpei Hu, Chinese Academy of Sciences, 55 East Zhongguancun, Haidian, Beijing, 100190, China, Chengjie Wang, Dan Yu, Jian Liu

The precision of ADT models heavily relies on the consistency of the testing environments and the corresponding assumptions. Recovery phenomenon is always observed when measurement conducted offline at low stress for some typical degradation failure modes. Statistical model and inference are proposed for this phenomenon, together with simulation results addressed.

#### 2 - WCF-Approach for Complex System Reliability Assessment

Dan Yu, Chinese Academy of Sciences, Beijing, China

System reliability assessment from component failure data is usually approximated by the central limit theory combined with delta method. A novel polynomial adjustment method for high reliability systems is adopted to construct higher-order approximate lower confidence limits, elaborated for log-location-scale family models with numerical studies conducted.

## ■ TC71

West Bldg 106C

### Geospatial Optimization Problems

Sponsored: Computing

Sponsored Session

Chair: John Gunnar Carlsson, University of Southern California, Los Angeles, CA 90089, United States

#### 1 - Equitable Partitioning of a Delivery Service Region with Orthogonal Blocks

Mehdi Behroozi, Boston, MA, United States

Motivated by the last-mile delivery service operation, we consider the problem of utilizing a fleet of vehicles over a rectilinear polygonal service region with orthogonal blocks and fixed vehicle depot locations so that all demand points are serviced and the workload is evenly distributed among the vehicles. We present an efficient algorithm for partitioning the territory into sub-regions using horizontal and vertical lines such that each sub-region contains exactly one vehicle depot location and the workloads of the vehicles, i.e. total traveled distance of the vehicle with respect to some natural metric, are balanced.

#### 2 - The Covering Path Problem on a Grid

Liwei Zeng, Northwestern University, Evanston, IL, United States, Karen Smilowitz, Sunil Chopra

This paper introduces the covering path problem on a grid (CPPG) which finds the cost-minimizing path connecting a subset of points in a grid such that each point is within a pre-determined distance of a point from the chosen subset. We leverage the geometric properties of the grid graph which captures the road network structure in many transportation problems. We develop a trade-off constraint which quantifies the trade-off between path length and stop count and provides a lower bound for the bi-objective optimization problem. We introduce simple construction techniques to provide feasible paths that match the lower bound within a constant factor.

### 3 - Distributionally Robust Travelling Salesman Problems and Variations

John Gunnar Carlsson, University of Southern California, 3750 McClintock Avenue, Los Angeles, CA, 90089, United States

Recent research on the robust and stochastic travelling salesman problem and the vehicle routing problem has seen many different approaches for describing the region of ambiguity, such as taking convex combinations of observed demand vectors or imposing constraints on the moments of the spatial demand distribution. One approach that has been used outside the transportation sector is the use of statistical metrics that describe a distance function between two probability distributions. Motivated by a districting problem in multi-vehicle routing, we consider a distributionally robust version of the Euclidean travelling salesman problem in which we compute the worst-case spatial distribution of demand against all distributions whose Wasserstein distance to an observed demand distribution is bounded from above.

#### 4 - Fair Division Approaches to Political Districting

Gerdus Benade, Carnegie Mellon University, 5000 Forbes Avenue, Pittsburgh, PA, 15213, United States, Ariel Procaccia

Gerrymandering and the problem of dividing a state into political districts are attracting a lot of attention. One of the difficulties in detecting gerrymandering is that it is hard to determine how many districts a party may expect to win. We approach districting as a fair division problem and propose a target number of districts for every party that is sensitive to the distribution of voters and the geography of the problem. We determine the extent to which this target can simultaneously be guaranteed to every party and propose a computational approach to districting.

#### 5 - Real World VRP Needs a GIS

Heather Moe, Product Engineer, Esri, 380 New York St, Redlands, CA, 92373, United States, Shubhada Kshirsagar

The Vehicle Routing Problem (VRP) becomes much more complex when the solutions need to be deployed in the real world. To produce an operational result, the VRP model must include geographically precise inputs. The best way to integrate this massive amount of information is to use a Geographic Information System (GIS) in the problem-solving methodology. This presentation will discuss requirements from a wide range of commercial and public-sector clients over 30 years?. With the described GIS inputs, the VRP model will produce a route plan that is both cost efficient and realistic.

## ■ TC72

West Bldg 211A

### Economics of Cybersecurity

General Session

Chair: Juhee Kwon, Korea Advanced Institute of Science & Technology (KAIST), Seoul, Korea, Republic of

#### 1 - Benefit Ambiguity and Asymmetric Herding in Privacy Decision: A Mobile Field Experiment

Youngsok Bang, PhD, The Chinese University of Hong Kong, Hong Kong, Jaehyeon Ju, Dong-Joo Lee, Jae-Hyeon Ahn

We conduct a field experiment with a self-developed mobile app to examine how the benefit ambiguity of using the app and others' permission setting affect users' permission on each of sixteen information items requested by the app. We find that participants who received the detailed reward scheme permitted more items than participants who received the abstract scheme. We also find that participants who permitted fewer items than the average were encouraged to permit more by getting the feedback of others' permission status, whereas participants who permitted more than the average were not affected. The asymmetric herding effect was greater for participants who received the detailed reward scheme.

#### 2 - Does Sharing Make My Data More Secure? An Empirical Study on Health Information Exchanges and Data Breaches

Liting Zhang, Temple University, Philadelphia, PA, 19122, United States, Sunil Wattal

This paper examines the IT security implications of hospitals joining a Health Information Exchange (HIE). Using IT governance theory and institutional theory, we propose hypotheses regarding the relation between a hospital joining an HIE and the likelihood that it suffers data breaches. We analyze a panel data for hospitals over a 6 year period empirically. Our preliminary results show joining HIEs mitigates security breach risks for hospitals. We also find that the mitigation effect is higher for hospitals with higher security capabilities and lower for large hospitals. The study contributes to the literature in IT governance, information security, as well as provides practical implications.

### 3 - A Cross Industry Study of Institutional Pressures on Organizational Effort to Raise Information Security Awareness

Hwee-Joo Kam, University of Tampa, Tampa, FL, 33606, United States, Thomas Mattson, Sanjay Goel

In this paper, we conceptually and empirically investigate the relationship between industry and information security awareness (ISA). To examine these potential industry effects, we draw on Neo-Institutional Theory (NIT). We specifically theorize that the pressures from the three institutional pillars (regulative, normative, and cultural-cognitive) will affect employees across all industries but the magnitude of those effects will vary across industries. To evaluate our theorized relationships empirically, we surveyed employees in the banking, healthcare, retail, and higher education industries.

### 4 - Do Data Breaches Impact Healthcare Market Share?

Juhee Kwon, Korea Advanced Institute of Science & Technology (KAIST), Hoe, Seoul, Kosovo, Republic of, M. Eric Johnson

Using propensity score matching combined with a difference-in-differences technique, this study examines whether hospitals observes changes in market share after a data breach. Accounting for geographically based competition in the U.S. healthcare sector, we find that data breaches significantly impact healthcare market share only in moderately concentrated markets where consumers have reasonable alternatives. We also find that the impact is much smaller in geographic regions with large health maintenance organizations plans. This implies that regionally dominant hospitals are able to endure breaches with little loss.

## ■ TC73

West Bldg 211B

### JFIG Panel Discussion: Advancing Your Research in Non-Doctorate Granting Institutions

Sponsored: Junior Faculty JFIG

Sponsored Session

Chair: Gokce Palak, Shenandoah University, Winchester, VA, 22601, United States

Co-Chair: Canan Gunes Corlu, Boston University, Boston, MA, 02215, United States

### 1 - JFIG Panel Discussion: Advancing Your Research in Non-Doctorate Granting Institutions

Canan Gunes Corlu, Boston University, 808 Commonwealth Avenue, Boston, MA, 02215, United States

Panelists will share their experiences, challenges and best practices in advancing research in non-doctorate granting institutions.

#### Panelists

Mesut Yavuz, Associate Professor, University of Alabama, Alston Hall Box 870226, Tuscaloosa, AL, 35487, United States  
Mihai M. Banciu, Bucknell University, College of Management, 119 Taylor Hall, Lewisburg, PA, 17837, United States  
Jeffrey D. Camm, Wake Forest University, School of Business, P.O. 7897, Winston-Salem, NC, 27109, United States  
Amit Eynan, University of Richmond, Robins School of Business, 1 Gateway Road, Richmond, VA, 23173, United States

## ■ TC74

West Bldg 212A

### Artificial Intelligence Based MCDM

Sponsored: Multiple Criteria Decision Making

Sponsored Session

Chair: Noor E. Alam, Northeastern University, Boston, MA, MA 02115, United States

### 1 - Consequence-based Framework for Municipal Infrastructure using Bayesian Belief Network

Golam Kabir, Assistant Professor, University of Windsor, CEI 3013, 401 Sunset Avenue, Windsor, ON, N9B 3P4, Canada, Ngandu B. Balek, Solomon Tesfamariam

The failure of municipal infrastructures like roads, water mains, sewers, bridges may cause crucial consequences to the health, environment, society, and economy. To develop an effective consequence-based framework, the data required from multiple sources and the relationship among the multiple consequence criteria is nonlinear and complex. In this study, a BBN-based sewer

consequence model is developed to handle the cause-effect relationships between multiple criteria and to prioritize the sewers for maintenance, repair, and replacement. The efficacy and the applicability of the proposed concept are demonstrated on the wastewater collection network of the City of Vernon, BC, Canada.

### 2 - Resilient Suppliers Selection: A Pragmatic Decision-Making Approach

Noor E. Alam, Northeastern University, 334 Snell Engineering Center, 360 Huntington Avenue, Boston, MA, MA 02115, United States, MD Mahmudul Hasan, Tasnim Ibn Faiz, Dizuo Jiang

This study aims to select resilient suppliers based on multi-criteria decision making approach, entailing both crisp and perception based information. To handle computing with words and crisp information in an integrated manner, a single valued neutrosophic sets and interval valued fuzzy sets in combination with TOPSIS was proposed, followed by a sensitivity analysis with respect to varying weight of the criteria.

### 3 - Big Data Driven MCDM

Noor E. Alam, Northeastern University, 334 Snell Engineering Center, 360 Huntington Avenue, Boston, MA, MA 02115, United States, Sharif Ullah

In this talk, we will introduce a decision making framework which can use Big data driven graphical information to make multi-criteria decision making.

### 4 - Multiobjective Adaptive Convolutional Neural Network for Medical Image Segmentation

Maria Baldeon, USF, 18322 Bridle Club Dr., Tampa, FL, 33647, United States, Susana Lai-Yuen

In this work we present an adaptive convolutional neural network for medical image segmentation. The AdaResU-Net consists of a fixed architecture and a learning framework that adapts the hyperparameters to the training dataset. The fixed architecture combines the favorable structure of the U-Net with a residual learning framework. The learning framework uses a multiobjective evolutionary algorithm to evolve networks with different hyperparameters subject to segmentation accuracy and model size as objective functions. Experimental results show that the AdaResU-Net is able to find competitive architectures with less than half the number of trainable parameters than competing networks.

## ■ TC75

West Bldg 212B

### Considering Human Aspects in Military Operations

Sponsored: Military and Security

Sponsored Session

Chair: Richard F. Deckro, Air Force Institute of Technology, AFIT/ENS Bldg 641, 2950 Hobson Way, Wright Patterson AFB, OH, 45433-7765, United States

### 1 - Dynamic-data-Driven Application System (DDAS) Based Multi-scale Simulation for Border Surveillance

Seunghan Lee, PhD Candidate, University of Arizona, Tucson, AZ, 85721, United States, Saurabh Jain, Young-Jun Son

Implementation of a robust border-surveillance system is challenging due to the information diversity and variability. We present an autonomous effective surveillance system based on multi-level simulation by deploying different types of sensors. Integration of agent-based and physics-based simulations will be developed and demonstrated for optimal planning and control of unmanned vehicles with a real-time geographic information system.

### 2 - Intersection of Human Aspects of Military Operations and Quantitative Decision-making

Kevin Kennedy

The JC-HAMO recognizes the centrality of human will, behavior, and decision-making in war and provides a framework that integrates into the Commanders Decision Cycle. The four central imperatives underpinning the concept are: "Identifying the range of relevant actors and their associated social, cultural, political, economic, and organizational networks". "Evaluating relevant actor" Anticipating decision-making. "Influencing the will and decisions of relevant actors" This discussion will show how research from various operations research fields have laid the groundwork to make this concept feasible.

### 3 - Linking Human Behavior to Campaign Planning: A Discussion of Some Modeling Approaches

Richard F. Deckro, Air Force Institute of Technology, Afir/ENS; Bldg 641, Department of Operational Sciences, Wright Patterson AFB, OH, 45433-7765, United States

The JC-HAMO calls for including aspects of a foes human behavior into campaign planning. This presentation reviews some of the modeling approaches available and suggests how they might begin to be included in campaign planning. After setting the stage, a participatory discussion is encouraged.



## ■ TC76

West Bldg 212C

### Joint Session MIF/HAS: Medical Decision Making

Sponsored: Minority Issues

Sponsored Session

Chair: Shannon Harris, The Ohio State University, Columbus, OH, 43203, United States

#### 1 - Revenue Management with Random Resources

Luis G. Vargas, University of Pittsburgh, Operations, Decision Sciences and AI, 356 Mervis Hall, Pittsburgh, PA, 15260, United States

We consider how to set the protection level in a system with two groups of customers when the resource demands of the customers are random variables. We operate a flat-fee legal clinic that serves both walk-in customers and those covered by employer-sponsored legal insurance. Consultation times are random obtained from historical data for customers of either type. Professional ethics require you to take customers on a first-come-first served basis and to complete a consultation no matter how much time it requires. Customers covered by legal insurance pay less for a consultation than do walk-ins. How much of the fixed opening hours of the clinic should you reserve for walk-in customers?

#### 2 - A Decision Support System for Augmentative and Alternative Communication Device Selection

Eduardo Perez, Assistant Professor, Texas State University, Roy F. Mitte Complex, 749 N. Comanche St., San Marcos, TX, 78666, United States, Mahima Sajan Varghese, Amy L. Schwarz

The goal of this research is to improve services for patients in need of Augmentative and Alternative Communication (AAC). In this talk, a methodology is presented to help selecting the devices to consider for a patient based on a disability profile. Currently, the decision-making process of what device to try on the patient is largely based on the health professional's experience and familiarity with specific devices or companies. The proposed models will limit patient discomfort and reduce device assessment time by helping in selecting the best fit based on the patient's disability profile.

#### 3 - Evaluating a Prediction Driven Targeting Strategy for Reducing Transmission of Multidrug Resistant Organisms

Sean Barnes, Univ of Maryland-College Park, 4352 Van Munching Hall, 20742, United States, Miranda Myers, Clare Rock, Daniel Morgan, Lisa Pineles, Kerri Thom, Anthony Harris

The transmission of multidrug-resistant organisms (MDROs) in the healthcare setting is an ongoing challenge. In this study, we leverage an agent-based model of MDRO transmission focusing on methicillin-resistant *Staphylococcus aureus* to develop and evaluate the effectiveness of a prediction-driven approach for targeting patients for intervention, based on their daily likelihood of becoming colonized by the organism. We show that we can predict these outcomes with moderate-to-high accuracy, and that these predictions can be used to efficiently target patients for intervention and ultimately reduce the overall acquisition rate across the entire unit.

#### 4 - CODAP: An Action Plan for Decision Making and Knowledge Discovery

Lincoln J. Chandler, Chandler Decision Services, 1224 S. Central Park, Floor 2, Chicago, IL, 60623, United States, William A. Massey

Motivated by a desire to support policy development and multidisciplinary collaboration, we propose an adaptable, iterative framework for managers and researchers. We refer to the action steps of the framework as CODAP, where: CODAP = Collect, Organize, Describe, Analyze, Prescribe. Taken in order, these action steps define a path of inquiry from observation (data) to informed response (policy). In a broader context, each individual action of CODAP aligns to a research narrative, with its own goal, motivation, and outcomes. In a literary sense, the narratives can be thought of as parts of a larger narrative, or saga. This talk will introduce the framework and provide some examples of application.

## ■ TC77

West Bldg 213A

### Evaluating Efficiency in the Public Sector

Sponsored: Public Sector OR

Sponsored Session

Chair: Ronald McGarvey, University of Missouri, IMSE and TSPA, Columbia, MO, 65211, United States

#### 1 - Health Center Efficiency and Quality of Chronic Disease Management: Associations with EHR Implementation

Andreas Holger Thorsen, Montana State University, 11 N. Chouteau Avenue, Bozeman, MT, 59718-6211, United States, Ronald G. McGarvey, Maggie L. Thorsen

Federally-qualified health center (FQHC) providers can receive federal incentives for activities such as participation in "Meaningful Use of electronic health records (EHRs)". While there is evidence of the positive impacts of EHR implementation, other research suggests that a focus on Meaningful Use can cause distractions and negatively impact health outcomes. Using national data, we conduct a data envelopment analysis to examine how quality and efficient care of patients with chronic conditions are associated with EHR implementation at FQHCs.

#### 2 - Woody Biomass use for Biopower and its Impact on Forest Resources

Ashkan Mirzaee, University of Missouri, Columbia, MO, 65201, United States, Ronald McGarvey, Francisco X. Aguilar

Energy derived from woody biomass is a major source of renewable energy in the U.S. Its use in biopower has experienced significant growth in recent decades. In spite of the ample use of wood in biopower, knowledge about its estimated impact on forest resources is limited. In this research, statistical analyses are performed to evaluate changes in forest attributes over time within wood procurement areas. An MILP model is then developed to minimize the total cost of generating the required electricity projected to be demanded by the EIA through 2030, with environmental and spatially-explicit woody biomass availability constraints.

#### 3 - Developing and Applying Predictive Models for Flood Impacts as Part of Advanced Operational Planning for Disaster Response

Kiatikun Louis Luangkesorn, Assistant Professor, University of Pittsburgh, 1028 Benedum Hall, 3700 Ohara St, Pittsburgh, PA, 15261-0001, United States, Sanjeev Goyal, Michael Whitehead

In a major disaster response, outside assistance is often delayed due to the need to determine what resources are required before identifying and mobilizing those resources. We use a predictive model to determine the resources required for mass care (feeding and sheltering) response following a major flood based on the use of real time flood gage and demographic information from the social vulnerability index. These predictions can be used as the basis for initial estimates of resource requirements to begin mobilizing resources in a more timely way, with adjustments being made as better information becomes available. This model has been used to inform the response to flooding in the U.S. in Spring 2018.

## ■ TC78

West Bldg 213B

### Alternative-Fuel Vehicles Refueling and Routing Problems II

Sponsored: Location Analysis

Sponsored Session

Chair: Ismail Capar, Texas A&M University, College Station, TX, 77843-3367, United States

Co-Chair: Yudai Honma, The University of Tokyo, Tokyo, 153-8505, Japan

#### 1 - Planning for Electric Vehicles: Maryland Case Study

Sevgi Erdogan, University of Maryland, College Park, MD, United States, Ismail Capar, Ibrahim Capar, Mohammad M. Nejad

Many states in the US have been deploying public battery charging stations to accelerate adoption of plug-in electric vehicles (PEVs). This research proposes an optimization-based approach to support EV infrastructure planning efforts. We use the flow-refueling location model to determine the location of public charging stations that would capture the maximum EV flow while preventing over-concentration of locations among other state specific policy constraints such as serving to designated EV corridors. We specifically use demand projections for years 2020 and 2040 for Maryland to create an electric vehicle charging network to facilitate long-distance travel throughout the state.

#### 2 - Promoting the Usage of Electric Vehicles Through the Efficient Design of Charging Station Network

Mohammad Miralinaghi, Purdue University, 550 W. Stadium Ave, West Lafayette, IN, 47907, United States, Gonzalo Correia, Sania E. Seilabi, Samuel Labi

This study proposes a framework to curb vehicular emissions by promoting the electric vehicle (EV) as an alternative to internal combustion engine vehicle on a long-term planning horizon in urbanized regions. In this framework, transportation planners seek to gradually install new electric charging stations by selecting new locations and/or repurposing existing gas stations. A bi-level model is developed to capture the decision-making process of both transportation planners and travelers. This study shows that as the transportation planner constructs EV charging stations, travelers are motivated to shift toward EVs which leads to significantly lesser vehicular emissions in the long run.

### 3 - Flow-capturing Location Problem with Capture Level Based on Detour Distances

Ken-ichi Tanaka, Keio University, Takehiro Furuta

We consider a flow-capturing location problem where capture level of each flow is dependent on the detour distance from a shortest path between origin-destination nodes. Two types of detour distances are considered. The first model assumes that a traveler deviates from the original path at the node nearest to a facility and then returns to the original path. The second model supposes that a traveler chooses a minimum-distance path between origin-destination nodes to visit a facility. We apply the two models to instances created from road networks and analyze optimal solutions.

### 4 - Collaborative Geodesign for Alternative Fuel Station Location using Open-source Collablocation Software

Michael J. Kuby, Arizona State University, School of Geographical Sci & Urban Planning, Tempe, AZ, 85287-5302, United States, Fangwu Wei, Keiron Bailey, Daoqin Tong, John W. Fowler, Qing Zhong, Oscar Lopez

We present an open-source collaborative GIS planning tool for facility location called Collablocation. Built with R, Shiny, MongoDB, and Open Street Maps, the first application is for natural-gas fueling stations for trucking across the Southwest. Results are presented from a pilot workshop with government and industry experts from five states.

## ■ TC79

Hyatt, Curtis A

### Supply Chain Management II

Contributed Session

Chair: Xun Xu, California State University-Stanislaus, One University Circle, Turlock, CA, 95382, United States

#### 1 - How Offline In-store Service Affects Online Drop-shipping Strategies in a Dual Channel System

Wei Lu, University of Science and Technology of China, Hefei, China, Jie Wu, Xiang Ji, Xiaohang Yue

We use a game-theoretical model to tackle the issue how the offline in-store service level affects online drop-shipping strategies in a dual channel environment. Our results show that when the retailer adopts a sufficiently aggressive in-store service strategy, the manufacturer (or the e-tailer) prefers drop-shipping rather than batch ordering even if it must sign a severe revenue-sharing contract. In addition, we show that when considering the retailer's in-store service strategies, the manufacturer's and e-tailer's preferences for drop-shipping are independent of the status of channel dominance.

#### 2 - The Role of Product Modularity on the Resilience of Multi-echelon Supply Networks

Yaneth Correa, Colorado State University-Pueblo, Pueblo, CO, United States, Roschele Henry

This work presents a simulation-based experimentation where instances of product modularity (represented by the BoM), define the structure of the supply network. The network is subject to random disruptions: node based and region based and a combination of both. The disruptions are represented by independent rare event statistical distributions. Network performance is evaluated using global (structural) and local (node) metrics.

#### 3 - The Effect of Carbon Tariff on Global Carbon Emission Control a Global Supply Chain Model

Yuan Fang, School of Management, University of Science and Technology of China, Hefei, China, Yugang Yu, Ye Shi

Motivated by the strategic production problem in a global manufacturing network, we study the impact of carbon tariff on the choice of production policies. Our paper conducts an analytical model to explore the operation decision by global supply chain managers under carbon tariff regulation. Exporting to domestic sales and invest green technology will be two candidates responses for suppliers without carbon reduction policies. Numerical examples in our paper further test our insights, and the outcome is consistent with our model analysis. We derive the optimal supply chain decisions for each case and find that carbon tariff policy is not always benefit for controlling global carbon emission.

#### 4 - Customer Concentration and Supplier's Corporate Social Performance

Jia Gao, PhD Candidate, Shanghai Jiaotong University, 1954, Huashan Road, Shanghai, 200030, China

Although there are extensive studies about Corporate Social Performance (CSP), our understanding of CSP in supply chain context is limited. In this study, we first identify the correlation between customer concentration and supplier's CSP. Then we investigate several key factors to help to explain this correlation.

### 5 - Examining Factoring Financing Strategies with Credit Insurance for Capital-constrained Supply Chain

Xun Xu, Assistant Professor, California State University, Stanislaus, One University Circle, Turlock, CA, 95382, United States, Nina Yan, Baowen Sun

This study examines and compares two factoring financing strategies: supplier insurance and factor insurance for supply chain using credit insurance. We use game theory models to find the optimal operations and financing decisions of supply chain participants, which include supplier, retailer, insurer, and factor. We find although the optimal decisions are different under the two strategies, both increase the profit of whole supply chain. We conduct empirical studies validating the modeling results. We provide implications of implementing factoring financing strategies to alleviate the SME retailers' financial constraints and enhance the supply chain performance.

## ■ TC80

Hyatt, Curtis B

### Practice- Supply Chain Management IV

Contributed Session

Chair: Matthew Petering, University of Wisconsin-Milwaukee, Industrial and Manufacturing Engineering Dept, Ems E367, Milwaukee, WI, 53201, United States

#### 1 - Sharing Demand Forecast with Common Retailer under Competition

Aditya Jain, Baruch College, Zicklin School of Business, 55 Lexington Ave, Suite 9-240, New York, NY, 10010, United States

We consider two competing manufacturers' decision to share private demand information with a common retailer. We show that the incentive to share information diminishes with competition intensity, which is contrary to existing results without competition, as well as investigate manufactures' investment in gathering information.

#### 2 - Strategic Management of Humanitarian Supply Chains for Disaster Relief and Readiness

Seong-Hyun Nam, Professor, University of North Dakota, 2517 Sand Hills Ave., Grand Forks, ND, 58201, United States

This research project will also examine the option contract pricing approach to the relief supply chain management and discuss in more detail about how the model presented in this paper can help the humanitarian supply chain managers make strategic decisions on their goal achievement.

#### 3 - Ranking of Key Supply Chain Enablers in Small and Medium Enterprise with Reference to Indian Handloom Sector

Tarunima Mishra, Research Scholar, Indian Institute of Technology, Kharagpur, D 507, Nivedita Hall, Kharagpur, 721302, India, Jitesh J. Thakkar, Kunal Kanti Ghosh

Handloom industry lies in SME which is the second largest sector providing employment to rural people in India but it is battling for its survival. This paper attempts to study and prioritize various enablers responsible for poor performance of small and medium industry while focusing on handloom industry with the help of interpretive structural modelling (ISM) and MICMAC analysis.

#### 4 - The Impact of Supply Chain Disruptions on Organizational Performance: A Literature Review

Mansoor Shekarian, Graduate Student, North Carolina A&T State University, Greensboro, NC, 27408, United States, Mahour Parast

This paper examines the effect of supply chain disruptions on organizational performance. We employ a systematic literature review to identify different conceptualizations and theorizations of supply chain disruptions, and to understand how different types of supply chain disruptions affect organizational performance. We later discuss organizational capabilities (resilience enhancers) that can improve an organizational response to supply chain disruptions. Finally, we outline future research directions in supply chain risk management and supply chain resilience.

#### 5 - Inventory Control with Flexible Demand: Cyclic Case with Multiple Batch Supply and Demand Processes

Matthew Petering, Associate Professor, University of Wisconsin-Milwaukee, Industrial and Manufacturing Engineering Dept, Ems E367, Milwaukee, WI, 53201, United States, Xi Chen, Wen-Huan Hsieh

We introduce, and present methods for solving, the cyclic inventory control problem with multiple flexible batch supply and demand processes. The objective of this new problem is to minimize the average or maximum amount of inventory of a single item that is held during a cycle of given length in a buffer whose stock is replenished by multiple batch supply processes and consumed by multiple batch demand processes. The problem is noteworthy in that the decision maker has control over the timing and lot sizes of all supply and demand processes. Thus, demand is flexible.

## ■ TC81

Hyatt, Phoenix East

### Optimization III

Contributed Session

Chair: Mohsen Mohammadi Dehcheshmeh, University of Louisville, 2301 S. 3rd St., Louisville, KY, 40292, United States

#### 1 - Designing and Optimizing an Integrated Platelet Supply Chain Network Considering Transshipment

Yuan Xu, PhD Candidate, North Dakota State University, 1045 17th Ave N. 161 Unit, Fargo, ND, 58102, United States, Joseph Szmerekovsky

Given the perishable and lifesaving characteristics of blood, unpredictable and unbalanced supply and demand incur a lot of waste due to expiry. Transshipment can help organizations deal with demand variability and stock outs, which will lead to a more balanced supply chain system. In this study, a mixed integer programming model considering blood transshipment for an integrated platelet supply chain is developed to minimize total operational cost under centralized control. The developed model considers multiple sources of supply and stock age information. Effects of demand variation, age composition, and transshipment will be analyzed.

#### 2 - Using Probability Dominance for Experimental Analysis of Algorithms

Hesam Shams, University of Tennessee, 851 Neyland Drive, 525 John D. Tickle Engineering Building, Knoxville, TN, 37996, United States, Oleg Shylo

We describe a framework for comparing optimization algorithms based on the concept of probability dominance. This approach provides a rigorous assessment of algorithms' performance, which is intuitive and statistically sound. It can be widely used as a tool for algorithm design and development in the operations research.

#### 3 - The Outcome Interval Problem

Mohsen Mohammadi Dehcheshmeh, University of Louisville, 132 Eastern Pkwy, J.B. Speed School of Engineering, Louisville, KY, 40292, United States, Monica Gentili

We introduce and study a new problem, namely the outcome interval problem, to quantify externalities in decision making under uncertainty. The outcome interval problem consists of determining the best and worst values of a given linear function (namely, the outcome function) over the optimal solutions of an interval linear optimization problem. We present some theoretical properties of the outcome interval problem and solve it heuristically and exactly. A comprehensive experiment is conducted to evaluate the performance of our methods and a real case study on healthcare access measurement is presented to show the importance of the problem for reliable decision making.

## ■ TC82

Hyatt, Phoenix West

### Health Care III

Contributed Session

Chair: Nooshin Hamidian, University of Tennessee-Knoxville, Knoxville, TN, 37920, United States

#### 1 - Improve the Quality of Care After Discharge by Selecting a Referral Network of Skilled Nursing Facilities

Yunsi Yang, Washington University in St. Louis, St. Louis, MO, 63130, United States, Fuqiang Zhang

Since the implementation of the Affordable Care Act (ACA), hospitals become more incentive to improve the care patient receive after discharge. To improve the efficiency of discharge planning, hospitals are seeking to collaborate with high-quality Skilled Nursing Facilities (SNF) and narrow down referral list. Bed reservation program and Preferred Network are two schemes commonly used to create the referral network. Considering hospital facing with uncertainty from patient choice and availability of SNF beds, we provide an algorithm for hospital to select a portfolio of SNFs for these two schemes.

#### 2 - Codified Knowledge Sharing and Operational Failures in Healthcare: Evidence From NHS Hospitals' Risk Management Documents

Mecit Can Emre Simsekler, Khalifa University of Science & Technology, Dept. of Industrial & Systems Engineering, Abu Dhabi, United Arab Emirates  
Mecit Can Emre Simsekler, UCL School of Management, London, United Kingdom, Bilal Gokpinar

Considering two key components of knowledge sharing among healthcare personnel, (i) codified in the form of written documents and (ii) tacit with behaviors and daily practices, we examine how knowledge sharing capabilities in healthcare settings translate into risk management performance. We employ a

unique dataset from the NHS acute trusts in England to investigate our hypotheses.

#### 3 - A Physicians and Medical Staffs Scheduling Problem in Hospitals with Multi-branches

Wenjuan Fan, Hefei University of Technology, No. 193 Tunxi Road, Hefei, 230009, China

This paper investigates the scheduling problem of physicians and medical staffs in large hospital with multi-branches. Each branch has its own medical staffs, while the physicians need to serve in all the branches affiliated to the hospital. The paper takes into account the demand and the available resources of the hospital, the workload of physicians and medical staffs, etc. as the constraints, and the objective is to minimize the dissatisfaction of physicians, and the cost of physicians. Then, a hybrid meta-heuristic algorithm SCA-VNS combining a Sine Cosine Algorithm (SCA) and variable neighborhood search (VNS) is proposed to solve this problem.

#### 4 - Control of an Infectious Disease in a Metapopulation

Ceyda Yaba, Clemson University, 110A Martin Circle, Central, SC, 29630, United States, Burak Eksioglu, Amin Khademi

An infectious disease for which there is no cure can quickly spread in a metapopulation with devastating consequences. Spreading of such a disease can be represented via a compartmental model. We modeled this problem as a Markov Decision Process, to control the spread of the infection by quarantining the infectious individuals. However, due to the curse of dimensionality, we solve the problem by an approximate dynamic programming (ADP) approach. We also compare the policy obtained from ADP with other benchmark heuristic policies, such as restless bandit, and one-step look-ahead policy. We then simulate our results for the 2014 Ebola epidemic in Sierra Leone.

#### 5 - House Calls and Office Visits: A Primary Care Model for Aging People Using Multi-objective Approach

Jennifer L. Mendoza-Alonzo, University of South Florida, Tampa, FL, 33613, United States, Jos Zayas-Castro

In the US, the elderly population will nearly double in the next 20 years. The primary care delivery system needs to be enhanced to face the new challenges of an aging population. Aligned with the health care reforms, this creates a "perfect storm for the development of house call models. This study analyzes from a strategic level, three perspectives: organization, patient, and care worker, in a mixed model-house calls and office visits- for people 65 years and older, using multi-objective optimization and Nash bargaining solution of an integer-programming model. It is expected to generate evidence about the possible benefits of this sub-model under the emerged model: patient-centered medical home.

#### 6 - Application of Mixture Model to Identify Risk Factors Corresponding to Heart Disease

Nooshin Hamidian, University of Tennessee-Knoxville, 851 Neyland Dr, Knoxville, TN, 37996, United States, Hamparsum Bozdogan, Rapinder Sawhney

This study explores critical features impacting heart disease for males and females. It investigates whether features contributing to heart disease significantly vary for males and females and determines the critical risk factors for both genders. A medical dataset, Cleveland dataset (UCI, 2009) is used. The Mixture model technique such as the kernel mixture model is applied to classify sick males and females. To select the best mixture models, we use information criteria such as ICOMP. The best mixture model identifies different subpopulations of patients. We study whether these subpopulations are associated with gender and determine the critical risk factors corresponding to each gender.

## ■ TC83

Hyatt, Remington

### Practice- Health Care III

Contributed Session

Chair: Haolin Feng, Sun Yat-sen University, Lingnan College, Guangzhou, 510275, China

#### 1 - Optimal Resource Allocation Policies in Nonprofit Organizations

Faisal M.M. Alkhannan Alkaabneh, Cornell University, Ithaca, NY, 14850, United States, Siddhartha Banerjee, H. Oliver Gao

We develop a framework for resource allocation, in the context of food banks operations, to help food banks optimize their share allocation policies by considering the nutrition needs of served population. To this end, we propose a convex programming model, a mathematical model whose solution provides a provable utility optimal policies. Through a novel mathematical model and the utilization of decomposition techniques, we arrive at two simpler sub-problems that can be solved efficiently. We prove that both sub-problems can be solved in polynomial time.



## 2 - New Models and Algorithms for Operating Room Scheduling Problems

Yang Wang, Associate Professor, Northwestern Polytechnical University, 127 West Youyi Road, Xi'an, 710072, China,  
Xue Yang, Haichao Liu, Haibo Wang

We propose new continuous and discrete mathematical programming models and design dedicated algorithms for solving operating room scheduling problems. The throughput of surgical patients, overtime of operating rooms and satisfaction of patients are optimized. Our algorithms incorporate new coding/decoding rules to represent feasible scheduling and dynamic programming guided scheduling strategy to significantly reduce computational time. We perform extensive experiments on both simulated and real-life hospital data to verify the merit of this study.

## 3 - Teaching Healthcare Process Management using Discrete Event Simulation

Chester G. Chambers, Asst. Professor, Johns Hopkins University, 100 International Drive, Baltimore, MD, 21202, United States

In this case study we use Discrete Event Simulation to teach about management of patient flow in an outpatient clinic. Students are provided with simulation models built using actual clinic data. Students explore issues involving patient punctuality, parallel activities, pre-processing, and appointment scheduling. This case has been used successfully with a wide array of students to teach about ways to develop process measures, experiment with process improvements, and evaluate potential results from interventions. The case serves as a course capstone to tie together elements of experimentation, process analysis, and process improvement.

## 4 - Optimal Experimental Design for a Partially Observable Simple Birth Process

Ali Eshragh, Senior Lecturer, The University of Newcastle, Newcastle, 2308, Australia

Our goal is to estimate the rate of growth,  $\lambda$ , of a population governed by a simple birth process. We may choose  $n$  time points at which to count the number of individuals present. But due to detection difficulties, we are able only to observe each individual independently with fixed probability  $p$ . We discuss the optimal times at which to make our  $n$  observations in order to maximise the Fisher Information for the birth rate  $\lambda$ . Finding an analytical form of the Fisher Information appears intractable. Nonetheless, we utilise the concept of generating functions to develop a new algorithm to maximise the Fisher Information. Our numerical results reveal the efficiency of this new algorithm.

## 5 - Clinic Scheduling with Patient Re-entrants

Haolin Feng, Sun Yat-sen University, Lingnan College, Guangzhou, 510275, China, Mark Lawley, Michelle M. Alvarado, Stephen Steidle

We consider a clinic scheduling with same-day patient re-entrants. The motivation is Mohs Micrographic Surgery (MMS), a surgical method for skin cancer excisions. It repetitively removes and examines one skin layer at a time until a cancer free layer is found. Current scheduling practice results in long in-clinic waiting and doctor overtime due to the stochastic nature of excision and pathology. We develop a model for MMS clinic scheduling to improve patient experience and clinic revenues. The model captures the key characteristics of the surgery-pathology and stochastic re-entrants. Theoretical results and numerical study based clinical data are provided to demonstrate the benefit of the method.

## 2 - Design Cost and the Birth of User Entrepreneurs

Ohchan Kwon, Harvard Business School, Wyss House, Soldiers Field, Boston, MA, 02163, United States

This paper examines how a reduction in design cost affects the entrepreneurial entry in the context of the video game industry. I exploit a sudden business model innovation of a major game engine software company, which provides the low-cost licensing option to some user innovators if their existing contents are compatible, but not others. I find that when the licensing cost decreases dramatically, user innovators are more likely to release independent games based on their prior innovation. The effects are stronger if the innovators' idea is of high-quality.

## 3 - Coexistence of Quality and Innovation an Automotive Perspective

Donna L. Bell, Wayne State University (Detroit, MI), Redwood City, CA, 94063, United States, Ratna Babu Chinnam, Julia Gluesing

In a time when the consumer electronics industry is getting new products to market at a rapid rate, automotive manufacturers must identify ways of getting new products and features to customers faster and with high quality to maintain or increase market share. We provide an analysis of the interviews and surveys completed by professionals of a global automotive company in understanding the impact that quality requirements have on innovation and the advanced product design process.

## 4 - Too Much is Not a Good Thing: The Inverted U-shaped Relationships of Average Tie Strength, Structural Holes, Intraorganizational Knowledge Search and Transfer

Wei Wang, PhD Student, Xi'an Jiaotong University, No.28, Xianning West Road, Xi'an, Shaanxi, 71, Xi'an, 710049, China, Xiaoming Sun, Antonio Capaldo, Wentian Cui

In this paper, we predict both average tie strength and structural holes exert inverted U-shaped effects on intraorganizational knowledge search and transfer by inventors and further suggest above relationships are flattener in key inventors compared to normal ones. Analysis of American patent data of 33 largest pharmaceutical firms worldwide from 1975 to 2014 offers support for our conjectures, except for the relationship of average tie strength and intraorganizational knowledge search, which is a gradually diminishing positive curve instead. We thus advance network research on knowledge flow by confirming the existence of curvilinear relationships and adding inventor attributes.

## 5 - Green Entrepreneurial Orientation for Enhancing Firm Performance: A Dynamic Capability Perspective

Wenbo Jiang, PHD, Northwestern Polytechnical University, Chang'an Compus, Xi, 710129, China

Despite much attention has been focused on the importance of green entrepreneurial orientation, its impact on environmental and financial performance remains unclear. Drawing on dynamic capability theory, we hypothesized that green entrepreneurial orientation has positive influences on two dimensions of firm performance, and green technology dynamism and knowledge transfer and integration play moderating roles in the relationship between green entrepreneurial orientation and firm performance. We tested the research hypotheses using data from 264 Chinese firms. This study enhances our understanding of green entrepreneurial orientation, as a dynamic capability applied in the firm.

## TC84

Hyatt, Russell

## Practice- Innovation/ Entrepreneurship I

Contributed Session

Chair: Wenbo Jiang, Northwestern Polytechnical University, 127 West Youyi Road, Beilin District, Xi'an Shaanx, 710072, China

## 1 - Advancing Digital Transformation: Integrating the Problem Space, the Solution Space, and the Quality Space for Successful Digital Transformation

Munir Majdalawieh, Associate Professor, Zayed University, Mirdif, Dubai, 19282, United Arab Emirates

Many c-suite executives are facing various challenges such as rigid processes, risk avoidance, digital disruption, interdepartmental conflict, disinterest in new ideas and complacency to move forward. These challenges require a vastly different approach to transform companies. The objective of this paper is to propose an integrated framework for problem space (design thinking), solution space (lean startup, Agile, SDLC), quality space (total quality management, six sigma) and change management space methods for successful digital transformation.

## Tuesday, 12:30PM - 2:30PM

## Tuesday General Posters

North Exhibit Hall E

## Tuesday Poster Session

Poster Session

Chair: Neng Fan, University of Arizona, Tucson, AZ, 85721, United States

Co-Chair: Junming Yin, University of Arizona, Tucson, AZ, 85721, United States

Co-Chair: Burcu B. Keskin, University of Alabama, Tuscaloosa, AL, 35406, United States

## 1 - Training Data Construction for Recommender Systems

Hanisha Vemireddy, Iowa State University, Ames, IA, 50011, United States, Sigurdur Olafsson

Recommendation systems provide predictions of user preferences based on prior ratings by the user. For users with only a few ratings, the quality of the recommendations may be low. Addressing this shortcoming, we develop an approach that uses modified rating for similar users to improve recommendations for the target user.

## 2 - Clustering with Incomplete Proximity Matrices

Samira Karimzadeh, Iowa State University, Ames, IA, 50011,  
United States, Sigurdur Olafsson

In data clustering, we sometimes only have an incomplete proximity matrix available to measure distance. This compromises the quality of the clusters, especially when values are not missing at random. Addressing this, our study proposes an effective graph theory method to complete values that are not missing at random.

## 3 - Sentence Embedding Module Satisfying a Characteristic of Human Language Recognition

Myeongjun Jang, Korea University, Seoul, Korea, Republic of,  
Pilsung Kang

Sentence embedding is an important topic in natural language processing (NLP). It is essential to generate a good embedding vector to enhance performance for many NLP tasks. So far, various models have been proposed and claim their superiorities through the good performance for sentiment analysis and text classification. However, since the performance of those tasks can be enhanced by using a simple sentence representation method, it is not sufficient to claim that they are good embedding methods. In this paper, inspired by human language recognition, we suggest the concept of semantic coherence that a good sentence embedding method should satisfy and propose the model to pursue this property.

## 4 - Prediction of Performance Deterioration for Solid Oxide Fuel Cell System

Jumpei Kawasaki, Tokyo Gas Co Ltd, Minato-ku, Tokyo, 105-8527,  
Japan

Although solid oxide fuel cell is an environmentally friendly system with high power generation efficiency and low carbon dioxide emissions, early fault detection and prediction of performance deterioration of the system components, especially fuel cell stacks, is required for further operation stabilization and maintenance optimization. In this study, the correlation of about 300 system parameters measured for 4000 hours and the power generation performance of the fuel cell stack is examined using machine learning technique, and performance deterioration prediction method is constructed which is expected to contribute for stabilization and cost reduction of operation.

## 5 - ELM-SOM: A Continuous Self-organizing Map for Visualization

Renjie Hu, Research Assistant Professor, University of Iowa,  
Iowa City, IA, 52242, United States

This paper presents a novel dimensionality reduction technique: ELM-SOM. This technique preserves the intrinsic quality of Self-Organizing Maps (SOM): it is nonlinear and suitable for big data. It also brings continuity to the projection using two Extreme Learning Machine (ELM) models, the first one to perform the dimensionality reduction and the second one to perform the reconstruction. ELM-SOM is tested successfully on six diverse datasets. Regarding reconstruction error, ELM-SOM is comparable to SOM while bringing continuity.

## 6 - Deep Convolutional Networks for Forgery Classification and Anomaly Detection

Zohreh Raziei, Southern Methodist University, Dallas, TX, United States, Xinyi Ding, Eric Larson, Michael Hahsler, Paul Krueger, Eli Olinick

We apply Convolutional Neural Networks (CNN) to identify fake photographs. Using medium-to-high-resolution images, we combine an auto-encoder-based neural network with explicit facial modeling to generate swapped faces of celebrities and compare the CNN's performance to approximate pairwise rankings inferred from judgement of human subjects.

## 7 - Optimal Design of Experiments on Riemannian Manifolds

Hang Li, Pennsylvania State University, State College, PA, 16803,  
United States, Enrique Del Castillo, George Runger

In recent years, scientists and engineers often need to deal with large volumes of high-dimensional data. Sometimes these data are available in a high-dimensional ambient space but they truly lie on a lower-dimensional manifold. The objective of this research is to develop theory of optimal experimental design on manifold data. In particular, we prove a new Equivalence Theorem for continuous optimal design on Riemannian manifold, and also provide a converging algorithm to find the optimal design.

## 8 - WeCureX Intelligent Psychiatry Assistant

Salih Tutun, Binghamton University (SUNY), Johnson City, NY, 13790, United States, Sedat Irgil, Ilker Yesilkaya, Ahmet Aykac, Nilay Aras, Begum Basaran Tutun

The aim of this research is to propose a new intelligent system (namely WeCureX) by using artificial intelligence approaches and psychometrics values for detecting major symptoms of social and personal maladjustment, assessing medical patients and design effective treatment strategies with high accuracy rates. Therefore, in this research, we will show how to identify symptoms for the SCL-90 test. We proposed optimized Lasso Logistic Regression and outlier detection. Finally, the results show that it works with 97% accuracy, and this system can be used by experts and patients for better treatment.

## 9 - A Framework for Five Big V's of Big Data and Organizational Culture in Firms

Thuan Nguyen, University of North Texas, Denton, TX, 76203,  
United States

Based on Cameron and Quinn's organizational cultural model, this study proposes a theoretical framework that describes how each type organizational culture - hierarchy, clan, adhocracy, and market - has an impact on each Big V of big data. The framework suggests that firms, influenced by their organizational culture, have different views on how important each Big V's should be. The study argues that organizations should develop, nurture, and maintain an adhocracy organizational culture that has a positive impact on each of the five Big V's of big data to harness the full potential of big data.

## 10 - Two Stage Aggregate Production Planning with Flexible Requirement Profiles

Setareh Torabzadeh, University of North Carolina-Charlotte,  
Charlotte, NC, 28262, United States, storabza@uncc.edu,  
Ertunga Ozelkan

This Research investigates on the aggregate production planning problem, using a flexible optimization approach, called: Flexible Requirement Profile, which enforces flexible bounds on production levels in different planning periods to improve the stability of the production plans. Due to the uncertainty of future periods demand estimation, the stochastic programming approach is incorporated into the optimization framework.

## 11 - Degradation Models of Biopolymers Under Accelerated Weathering Conditions

Elias Arias Nava, New Mexico State University, Las Cruces, NM, 88001, United States, Delia Valles-Rosales

Research in renewable products with the potential to replace fossilized matter as raw materials for energy and materials use is at the forefront of modern science and engineering. This project designs new degradation models that could provide reliable lifetime data of biopolymers. The goal associated with this study is to present a new degradation model(s). Specimens were manufactured under ASTM standards using extrusion and injection molding; followed by 2000 hours of accelerated degradation test. The accelerating variables were: temperature, humidity, UV exposure and time. Multivariate analysis of five responses were analyzed: tensile, flexural, color change, mass loss, and FTIR analysis.

## 12 - Berth Scheduling at Marine Container Terminals: Minimizing Carbon Dioxide Emissions Due to Container Handling

Maxim A. Dulebenets, Florida A&M University-Florida State University, Tallahassee, FL, 32311, United States, Olumide Abioye, Ren Moses, Eren Erman Ozguven, Arda Vanli, Thobias Sando

This study presents a mixed integer programming model for the green berth scheduling problem, which accounts not only the total vessel service costs, but also considers the cost associated with the carbon dioxide emissions produced due to container handling. A set of Hybrid Evolutionary Algorithms are proposed to solve the mathematical model. Numerical experiments demonstrate that introduction of local search heuristics within the developed algorithms improved the quality of the obtained solutions. Furthermore, changes in the carbon dioxide emission cost influence the berth schedule design.

## 13 - Dynamically Scheduling National Football League Games to Reduce Strength of Schedule Variability

Jamie Fravel, Furman University, Greenville, SC, 29613, United States, Elizabeth Bouzarth, Andrew Cromer, Ben Grannan, Kevin Hutson

The NFL schedules games where some matchups are based on the previous year's results. Since team composition changes from year to year, this scheduling policy sometimes benefits teams unfairly, allowing some an easier path to the playoffs than others. Thus, strength of schedules vary between teams and arguments have to be made why some teams make the playoffs and others do not. We propose methods to produce an NFL schedule that combines some of its traditional elements with dynamically-scheduled games aimed at optimizing different objectives, such as reducing the variability of teams' strengths of schedules or minimizing the number of pairwise comparisons needed to differentiate team quality.

## 15 - User-based Rebalancing Approach for Free-floating Bike Sharing Systems

Yan Wang, The University of Hong Kong, Hong Kong, Hong Kong, Junwei Wang

This work studies the rebalancing problem in FFBS, which aims at reconfiguring the spatial and temporal distribution of bikes so that supply matches demand. We propose the first model specially designed for FFBS. Based on our original Radiant Service Theory (RST), the model describes the real-time status of the system. Also, we develop the first user-based rebalancing approach for FFBS. A dynamic incentive mechanism that encourages users to change parking places to problematic locations is presented. Finally, simulation results show the effectiveness of the mechanism and suggest it best fits a system with modest bike amount, high unbalance degree, and users sensitive to incentives.

**16 - Framing in Supplier Selection Problem**

Somaye Ramezanzpour Nargesi, PhD Candidate, University of Texas at Arlington, Arlington, TX, 76015, United States, Kay-Yut Chen

One of the crucial steps of procurement process is supplier selection. Assuming that the supply management of the company is single sourcing, the real problem will be a multi-attribute trade off decision to choose one supplier from several. In this research we tackled this problem from behavioral economy stand point. We administered experimental design to investigate the effect of two types of framing (Content and Information Framing) on this multi-attribute trade-off decision and found out that both types of framing matter in a meaningful way.

**17 - Impacts of Government Subsidies on Cooperative Game Pricing for China Railway Express and Freight Forwarders**

Jingru Ren, Southwest Jiaotong University, Chengdu, China, Yinying Tang, Qinglin Li, Weidong Dai

China's subsidies to China-Europe express can be divided into subsidies for CHINA RAILWAY Express and freight forwarders. To study the impacts of subsidies on cooperative pricing strategy for the Express and forwarders, considering market demand fluctuation, the Stackelberg game model under different subsidy objects and Nash model under non-subsidy situation have been established. The optimal contract pricing strategy, freight volume and market pricing strategy have been obtained. A numerical example has been used to verify the validity of the models and to analyze the impacts of different subsidy policies on both sides' revenue and supply chain revenue when market demand fluctuates.

**18 - Project Team Communication and Understanding Cycles of Mental Model Convergence**

Deanna Kennedy, Associate Professor, University of Washington, Bothell, WA, 98011-8246, United States

Project teams are thought to produce better quality outcomes than individuals working alone. Yet, given the inconsistency of teamwork effectiveness found by researchers for at least the last 35 years, there is still much to be learned about why teams achieve, or fail to achieve, more than the sum of their parts. Herein, I look at team mental models, cognitive repositories containing abstract representations relevant to taskwork and teamwork activities, and model the system to understand the dynamics of shared and accurate team mental models over time. This research uses agent based modelling and particle swarm optimization to study the system and provide preliminary analysis about teams over time.

**19 - The Effects of Manager's Perception on Intellectual Property, Innovation, and Firm Performance**

Giyoon Kwag, Illinois Institute of Technology, Chicago, IL, United States, Sejun Park, Taewoo Roh

Analyzing survey data from CEOs collected by Science and Technology Policy Institute (STEPI) in South Korea, we establish further understandings on the Intellectual Property (IP) and its impacts in the perspective of CEOs. The research investigates how the CEOs' attitude toward IP affects the firm performance through product, process, organization and marketing innovations. This study examines the direct and indirect effects of IP on innovation and financial performance with the structural equation method (SEM) and captures the mediating role of innovation between IP and financial benefits.

**20 - Stochastic Programming-based Bypass Strategy for Acute Stroke Patients and EVT Resource Re-distribution**

Ting-Yu Liu, National Tsing Hua University, Hsinchu, Taiwan, Ming-Ju Hsieh, Chun-Han Wang, Yu-Ching Lee, Wen-Chu Chiang

The prognosis performance of endovascular therapy (EVT) is shown better than thrombolysis in the patients with acute ischemic stroke (AIS) caused by large vessel occlusion in recent clinical medical research. Yet EVT resources are available only in a few number of comprehensive stroke centers. According to stroke symptom severity and geographic information, we develop a bypass strategy for AIS patients using a stochastic programming model to decide a comprehensive stroke center where the patient should be sent. Policy of reduction or expansion of EVT hospitals can further be facilitated.

**21 - An Integrated Approach to Train Timetabling and Rolling Stock Circulation in Urban Rail Transit Lines**

Bum Hwan Park, Korea National University of Transportation, Uiwang, Korea, Republic of

There have been many tries to reduce travel time in rail transit. One of them is to diversify the stop patterns to provide faster trains to the passengers. Diversifying the patterns makes it difficult to find an optimized plan since there are some operational constraints like overtaking, complicated headway to consider. And a rolling stock circulation can not be easily found due to different running times. We present a network model to consider timetabling and rolling stock circulation, simultaneously. We first find a circulation with available stocks, which may be not feasible. And then the model finds an optimal circulation with shifted arrival and departure time by column generation approach.

**22 - Optimizing Green Infrastructure Placement Under Precipitation Uncertainty**

Masoud Barah, University of Tennessee, Knoxville, TN, 37996-2315, United States, Anahita Khojandi, Xueping Li, Jon Hathaway, Olufemi A. Omitaomu

Green Infrastructure (GI) practices are low cost, low regret strategies that can contribute to urban runoff management. However, questions remain as to how to best distribute GI practices through urban watersheds given the precipitation uncertainty and the hydrological responses to them. We develop a stochastic programming model to optimize placement of GI practices in a watershed to minimize the excess runoff under medium-term precipitation uncertainties. The model was calibrated using precipitation projections and the associated watershed hydrologic response. The optimal GI placement is identified for an urban watershed in a mid-sized city in the U.S.

**23 - A Three-level Defender-attacker-operator Problem Against Cyber-attacks in Electric-gas Systems**

Bining Zhao, Lehigh University, Bethlehem, PA, 18015, United States, Alberto Lamadrid, Rick Blum

The interdependence between natural gas and power systems is increasing rapidly. Availability of natural gas for gas-fired units can impact the secure operation of power systems. Fuel supply shortage for gas-fired generators can be caused by uncertain interruptible supply and incorrect supply information. This work proposes a trilevel min-max-min optimization problem to provide the power system operator a practical tool to protect critical fuel supply information from man-in-the-middle cyber-attacks, and also the strategies to sign firm supply contract to reduce gas supply uncertainties. Column and constraint generation (C&CG) algorithm is employed to solve the proposed problem.

**24 - Dandelion Algorithm: A New Meta-heuristic Based on the Wind Markov Chain**

Kihyuk Yoon, UNIST, Ulsan, Korea, Republic of, Jongkyung Shin, Chiehyeon Lim, Chiehyeon Lim

This work proposes a new meta-heuristic algorithm called the dandelion algorithm (DA). The DA is inspired by the dispersal of dandelion seeds by wind. Such dispersal can be considered as a random walk for optimization and may be affected by flower height (i.e., objective value) as well. In the DA, the two essential phases of optimization, exploration and exploitation are achieved during the designed mechanisms of planting, growth and survival, and seed dispersal. Several engineering problems are used for evaluation, and the result is compared with those of several existing algorithms. Results show that the proposed DA is powerful.

**25 - Algorithms for the Mean Steady-state Waiting Time in the GI/GI/1 Extremal Queue**

Yan Chen, Columbia University, New York, NY, 10027, United States, Ward Whitt

The effective algorithms are developed to compute the steady-state mean waiting time of extremal GI/GI/1 queues. We establish two reductions for an extremal queue, reducing it to D/GI/1 and GI/D/1. The idle time simulation algorithms are exploited to estimate first two moments of idle time and then compute E[W] by associated equilibrium excess distribution of idle time. Also, the paper exploits fast numerical algorithms for the extremal queue, one is using the negative binomial recursive formula, and another is considering an equivalent discrete-time Markov chain recursion. The computational results for different cases of c2a, c2s are compared with known approximations and bounds.

**26 - Dynamic Routing in a Many-server System with Costly Information**

Junfei Huang, The Chinese University of Hong Kong, Shatin, N.T., Hong Kong

We study a multiple-station queueing system with a single class of customers and many servers in each several stations. Upon a customer's arrival, the system manager decides which station the customer should be routed to. The station information retrieval is costly. We propose routing policies that are proved to be asymptotically optimal in minimizing the long-run average waiting cost plus the information retrieval cost.

**27 - Revised Adaptive Linear Programming Algorithm**

Lin Guo, The University of Oklahoma, Norman, OK, 73071, United States

We revise the Adaptive Linear Programming (ALP) algorithm. ALP is a linearization algorithm with limitations: its critical parameter Reduced Move Coefficient (RMC) is determined with heuristics and there is no mechanism of updating it to get more desired solution; little knowledge on the association between RMC and model behavior has been explored; no generic criteria for the designer to evaluate the quality of the results. To fill in the gaps, we revise the algorithm by using the insight obtained from post-solution analysis into the critical parameter updating to remove the heuristics. We use a test problem to examine the performance of the revised ALP algorithm and validate its advancement.



**28 - Land-use Optimization of a Watershed for Nutrient Reduction Under Stochastic Weather Conditions**

Gorkem Emirhuseyinoglu, Iowa State University, Ames, IA, United States, Sarah M. Ryan

Agricultural runoff causes nutrient loads in waterways and creates a hypoxia zone downstream, which threatens oceanic life. We build a land-use optimization model to minimize the cost for a watershed to meet target reductions in nitrate and phosphorus levels under stochastic weather conditions. Results are illustrated using an online tool.

**29 - Stochastic Programming Models to Plan for Distributed Generation Under Wind Power Volatility**

Clara Novoa, Associate Professor, Texas State University, Clara Marcos, TX, 78666, United States, Temitope Runsewe, Jordan Givens, Tongdan Jin

We present non-linear stochastic integer programming models to find the optimal wind turbine capacities and locations that minimize costs of adopting renewable energy considering loss-of-load probability, thermal constraints, and volatilities on wind turbine power generation. The models solve exactly and through simulation optimization. The models include scenarios that represent the wind speed across the turbine blades over the different operational phases of the wind turbines. Wind speed data collected for Wellington, New Zealand and Rio Gallegos, Argentina permit to estimate the probabilities associated to the scenarios and illustrate the benefits of the stochastic models.

**30 - Stochastic Dynamic Markov Decision Process on Airport Security Checkpoint Demand Shifting**

Nigel Pugh, PhD Student, North Carolina A&T State University, Greensboro, NC, 27409, United States, Hyoshin Park

Airport Delays known to cost airport operation of U.S. airlines billions of dollars each year. In this paper, we focus on reducing airport congestion from both passenger and airport operations perspectives. This is accomplished through incentivizing the passenger to switch arrival times to encourage a system optimal. The demand is then used as an input for worker assignment problem of switching airline workers based on current demand. A Markov Decision Process is proposed to maximize reward by making best decision of whether to switch airline worker security checkpoint location depending on the current demand of the congestion state.

**31 - Data Analytics in Agricultural Business**

Hieu Pham, Syngenta, Slater, IA, 50244, United States

Advancing analytical techniques in agriculture are vital to satisfying increased food demand. At the forefront of the agricultural data science, revolution is Syngenta with innovative machine learning algorithms (sparse biclustering) and novel optimization models (portfolio selection) to mitigate world hunger.

**32 - A Novel Dynamic Routing Framework for Shared Mobility Services**

Yue Guan, Massachusetts Institute of Technology, Cambridge, MA, 02139, United States

Shared Mobility on Demand (MoD) services like Uber, Lyft, and Didi have shown that a continuum of solutions can be provided between traditional private transport and public mass transit. Here we propose a novel shared MoD framework which generates a dynamic route for multi-passenger transport, using a new concept of space window that introduces a degree of freedom to help reduce system cost in designing the optimal route. An Alternating Minimization based algorithm is developed. Its analytical properties are characterized. Detailed computational experiments are carried out that demonstrate its advantages in computational efficiency and optimality compared to standard optimization solvers.

**33 - An Agent-based Simulation Model for Assessing a Charging Infrastructure Design for a Public Electric Vehicle Charging Network**

Long Zheng, University of Louisville, Louisville, KY, 40217, United States, long.zheng@louisville.edu, Lihui Bai

We present an agent-based simulation model for performance assessment of the infrastructure design of a public EV charging network. The model, comprised of three agents (EV, battery and charging station), is capable of handling heterogeneous trips in an urban traffic network (e.g., commute, shopping). Further, the model considers a mix of charging sources: public, home charging and workplace charging, available to the EV fleet. The model can be used in conjunction with an optimization model for an optimal design of the charging infrastructure at both strategic and operational levels.

**34 - A New Markov Processes Methodology for Identifying Screening Strategies for Breast Cancer in Low- and Middle-income Countries: Application to Peru**

Vijeta Deshpande, University of Massachusetts, Amherst, MA, 01002, United States, Chaitra Gopalappa, Shifali Bansal

Peru is currently in preparation of a national 'investment case' for the prevention of premature mortalities from non-communicable diseases including breast cancer. This is informed by quantitative economic analysis of current and future health interventions. We apply a Markov process method for

parameterization of a natural cancer progression model for conducting an economic analysis of interventions for Peru. We also apply a Markov decision process model for identifying optimal number of mammography screenings and ages to screen, under different willingness to pay per life-year saved to model the trade-offs in costs and impacts.

**35 - Prediction of Inpatient Length of Stay Using Bootstrap Aggregating Machine Learning Algorithm**

Sohong Chakraborty, California State University, Los Angeles, CA, 90032, United States, Shilpa Balan, Divya Pakhale

Hospitals face the daunting task to provide timely patient care. This research aims at improving the inpatient admission rate by predicting the length of stay in an inpatient care facility. A National Inpatient Sample (NIS) data for the year 2013 is considered for this study, which is available through the Healthcare Cost and Utilization Project (HCUP). We predicted the length of stay of patients using the Bagging or Bootstrap aggregating algorithm. The independent variables considered for this study are age, diseases, diagnosis categories, time of admission, hospital charges and emergency department services. The correlation coefficient for the inpatient length of stay is found to be 0.842.

**36 - A Latent Markov Model for Predicting Return to Work for Injured Workers**

Suyanpeng Zhang, University of Michigan, Ann Arbor, MI, 48109, United States, Haozhu Wang, Mukai Wang, Brian T. Denton, Jenna Wiens, Jon Seymour

We present a data-driven approach based on the use of latent Markov models for predicting the probability of returning to work for workers injured in the workplace. We show how models fit to observational longitudinal data on injuries and follow-up procedures and treatment can be used to classify patients based on sequential observations over time. We demonstrate the proposed approach using longitudinal data from a large national data set.

**37 - Stochastic Optimization Algorithms for Robust Medical Decision Making**

Vinayak Ahluwalia, University of Michigan, Ann Arbor, MI, 48109, United States, Charmee Kamdar, Lauren N. Steimle, Brian T. Denton

Healthcare is increasingly reliant on mathematical models, such as Markov Decision Processes, to monitor disease progression and improve patient care. To address the abundance of parameter ambiguity from clinical data, the Multi-Model Markov Decision Process (MMDP) was invented. We designed a custom branch-and-bound algorithm to solve large, practical MMDPs that was orders of magnitude faster than commercial mixed-integer programming software, for a set of test cases. In addition, we implemented various objective functions allowing for different risk preferences towards parameter ambiguity. We present a relevant medical decision-making case study to illustrate our approach.

**38 - An Analytic Approach to Incorporate the Six Aims for Quality in the Analysis of Trauma Care Services**

Lucy Aragon, Wichita State University, Wichita, KS, 67260, United States, Laila Cure, Karen Schieman

The Institute of Medicine proposed six aims to guide healthcare quality improvement efforts. However, most healthcare improvement programs still evaluate quality along one aim at a time, effectiveness. This research proposes an analytic approach to incorporate all six aims in the evaluation of healthcare quality. A trauma care setting is used to investigate data requirements, develop the methodology and evaluate its implications.

**39 - Impact of Referral Strategy on a Medical Network**

Shao-Jen Weng, Associate Professor, Tunghai University, Taichung City, 407, Taiwan, Ping-Wen Huang

Hospital emergency departments have been becoming more congested, and thus one issue of interest is how to better allocate limited medical resources and make more effective medical care referral strategy decisions. This study thus uses the system simulation to design and simulate a medical system for analyzing different kinds of referral strategies to enhance medical bed usage efficiency in each hospital, and promote the quality of service offered by shortening the waiting times of patients with regard to getting a medical bed.

**40 - Multi-method Simulation Modeling of the Hospital Readmission Reduction Program**

Arlen Dean, Arizona State University, Tempe, AZ, 85281, United States, Michelle Alvarado

The Hospital Readmission Reduction Program (HRRP) was enacted to penalize hospitals with poor readmissions. A multi-method simulation model is created to capture the interaction of hospitals and the insurer under the HRRP. The goal is to improve healthcare quality by studying how a payment adjusting policy affects hospital decision making.

**41 - Addressing Parameter Ambiguity in Medical Decision Making**

Charmee Kamdar, University of Michigan, Ann Arbor, MI, United States

Data driven mathematical models are increasingly being used for medical decision making. However, the parameters used in the mathematical models can be imprecise due to scholarly disagreement or small input data sizes. One way to account for this ambiguity in a Markov Decision Process (MDP) is to use a Multiple Model Markov Decision Process (MMDP) that has many different transition probability matrices. Using an MMDP results in a treatment policy that is more robust to changes in the transition probability matrix. This poster discusses how to construct MMDPs from observational data.

**42 - A Clustering Based Decision Tree Approach for Risk Assessment of Information Security in Smart Cities**

Yana Yuan, PhD Candidate, Northwestern Polytechnical University, Xi'an, 710129, China, Huaqi Chai

The emergence of new information technologies poses challenges to information security in smart cities. Risk is the most prominent challenge. In this paper, we analyze the impact factors of information security in smart cities and evaluate the risk that these factors bring to information security. We aim at establishing a new evaluation index system and building a risk assessment model based on Ward's method and decision tree. Then we present an empirical study on risk assessment of information security in 15 smart cities. We provide a data-based and intelligent method to assess the risks of information security, and give solutions to address the challenges for information security in smart cities.

**43 - Estimating and Analyzing Hazardous Material Flows in Oklahoma**

Ronny Pacheco, Oklahoma State University, Stillwater, OK, 74075, United States, Manjunath Kamath, Farzad Yousefian, Scott Frazier, Babak Farmanesh, Goutham Takasi

We present a unique survey-driven hazardous material flow estimation model for the state of Oklahoma. Our approach begins with a database of Oklahoma commercial facilities, which store materials considered as extremely hazardous substances (EHS). A web-based survey targeting these facilities is used to collect shipment data for the EHS materials handled by these facilities. Shipments are then assigned to routes identified using a shortest path algorithm. A GIS application is being developed to analyze and visualize the flow patterns and intensities of the various EHS materials transported. The results will be useful to Local Emergency Planning Commissions in planning for emergencies.

**44 - Efficiency Study in Public Tenders: Analysis of Framework Agreements in Chile.**

Eduardo Lara, Universidad de Chile, Santiago, 8370456, Chile, Marcelo Olivares, Gabriel Weintraub, Daniela Saban

Framework Agreements (FA) is a commonly used procurement mechanism by governments and large organizations. It is based on an auction-type design to select an assortment of products from multiple suppliers with posted prices, allowing some flexibility and variety to purchasing units. The design of FA requires balancing competition to enter the market with the variety offered inside the market. This paper conducts an empirical study of the FAs used by the Chilean government, identifying inefficiencies in the procurement market, providing improvements to design and conducting a field study to measure the actual effectiveness of the new implemented design.

**45 - The Effects of Video Game Players' Emotions and Experiences on Online Review Ratings**

Pei-Hua Chen, National Chiao Tung University, 1001 University Road, Hsinchu, 300, Taiwan, Li-Chien Cheng

Previous literature suggested that consumers prefer to make purchasing decisions based on online user-generated contents. This study investigated the different effects of video game players' emotions and game playing experiences on professional and general consumer reviews ratings for different kinds of video game genres. Text mining techniques was used to investigate the effects of polarity of online reviews, emotions and gaming experiences on video game sales on amazon.com. The results showed that factors affect review ratings for different genre of games are not the same.

**46 - An Intelligent Design Assistant System Development:****A Case of the Korean Shipbuilding Industry**

Jun-Mo Nam, Ulsan National Institute of Science and Technology (UNIST), Ulsan, Korea, Republic of, Dong-Joon Lim, Yeo-Myung Rho, Je-Kyung Kim, Wook-Hyun Cha

This poster presents a development case of an intelligent design assistant system that can give an insight into: 1) optimal scheduling based on workload estimation; 2) response-bot based on past communication records with shipowners; and 3) design verification based on revision log analysis. We adopt various machine learning techniques including the gradient boosting and similarity matching algorithms to replicate experts' decisions recorded in the legacy system. The system has been successfully integrated into the newly developed project management system and is expected to be deployed as a part of the Smart Shipyard Program of Korea by 2019.

**47 - Modeling Human Decision Making Behavior in Simulation**

Farhad Moeeni, Professor, Arkansas State University, Jonesboro, AR, 72467, United States, Karen Yanowitz, John Seydel

The purpose of this study is to acquire insights into the behavior of people when they encounter waiting lines. It is expected that several theories of decision-making to be examined by this study through controlled laboratory experiments. The first objective is to identify and possibly quantify the important factors that influences people's behavior when they encounter waiting lines, for example balking and renegeing. The second objective is, to apply what we learn, as a result of investigating the first objective, to optimize the queueing systems from the perspectives of both service receivers and service providers.

**48 - Gaussian Mixture Model Based Random Search for Continuous Optimization via Simulation**

Wenjie Sun, Tongji University, Shanghai, China

This paper studies integrated random search algorithms for continuous optimization-viasimulation (COvS) problems. We first tailor the Gaussian process-based search (GPS) algorithm to handle COvS problems. We then analyze the potential sampling issue of the GPS algorithm and propose to construct a desirable Gaussian mixture model (GMM) which is amenable for efficient sampling and at the same time also maintains the desirable property of exploitation and exploration trade-off. Then, we propose a Gaussian mixture model-based random search (GMRS) algorithm. We build global convergence of both the tailored GPS algorithm and the GMRS algorithm for COvS problems.

**49 - An Integrated Simulation Optimization Framework For Controlling A Biological Invader**

Sevilay Onal, NJIT, Newark, NJ, 07103, United States, Najmaddin Akhundov, Esra B y ktahtak Jennifer Smith, Gregory R. Houseman

An aggressive invasive plant, *Sericea*, reduces the abundance and diversity of native plants and causes large economic damage in the Great Plains of U.S. We present an integrated simulation-optimization framework to control this invader. Simulation mimics *Sericea* growth over space and 12 years, while a bio-economic optimization model finds an optimal search and treatment path to minimize its economic damage.

**50 - Consolidation of Picked Orders in a Fulfillment Center with Explosive Storage**

Wen Zhu, New Jersey Institute of Technology, Newark, NJ, 07102, United States, Sanchoy Das

Online fulfillment warehouses, similar to those used by Amazon, typically operate an explosive storage policy. That is, each item is stocked in multiple random locations dispersed throughout the warehouse. Orders are then picked and collected in totes which are assigned to one of many packaging stations. Each multi-item order is therefore located in several totes and must be consolidated or rebined at a packaging station. A perfect assignment is not possible. We formulate the problem a MIP and present a fast heuristic solution.

**51 - Multi-attribute Supplier Selection Model**

Mazen Hussein, Assistant Professor, University of Wisconsin-Platteville, Platteville, WI, 53818, United States

The main purpose of this work is to create a fuzzy logic model to select the most appropriate supplier based on the lowest reduction rate with multiple attributes. A mechanism with certain criteria is used to evaluate the suppliers and then select the best alternative among them.

**52 - Multi-level Reverse Supply Chain Redesign Under Unknown Facility Capacity**

Jieyu Lei, Northwestern Polytechnical University, Xi'an, China

Technological innovation motivates consumers, especially the young, to chase after new products constantly. Lots of old products has been put aside or dropped randomly. How to reuse these waste resources has been an urgent issue for many countries. This research aims to solve the problem by designing a multi-echelon reverse supply chain. We modeled a network optimization problem using the mixed integer planning approach and proposed a heuristic algorithm to calculate the optimal designing choice. The results show that through the model, we can not only get the optimal location and transportation scheme, but also the optimal capacity decision for new facilities.

**53 - Estimate the Characteristics of Truck Flow Based on Spatial Scale**

Fadong Zhang, Southwest Jiaotong University, Chengdu, 610031, China, Mi Gan, Xinyuan Li

This paper takes the truck trajectory data as the research object, classifies it by transportation efficiency index, and uses statistical physics method to probe the distribution of travel trajectory, transportation distance and freight volume of the individual truck, and the group trucks. At the same time, through the regression analysis of the relationship between the unload rate of trucks and the transportation distance and transportation capacity, the interaction characteristics of the probability distributions are explored, and the mechanism of the influence of truck mobility characteristics on the no-load rate of road freight is explained.

#### 54 - Research on the Application of Daul-cost Control Standard in Railway Freight Transportation Enterprise

Li Luhui, South West Jiao Tong University, Cheng Du, China,  
Tang Yinying, Zhu Xinglong, Lv Dong

Daul-cost control standard, as one of the latest methods of costing control, has been almost used in manufacturing enterprise. To study the application of Daul-cost control standard in railway freight transportation enterprise, this paper combines the activity-based costing and the benchmark-model dual-cost control standard together, and produces a new cost control model. Then the DEA method is used to evaluate the performance of activity-based costing control with double standards. At last, this paper proposes specific measures of cost control with double standards as well as incentives from the environment of railway freight transportation enterprise.

#### 55 - Intra-hub Transportation Simulation

Mohammad Torkjazi, University of South Carolina, Columbia, SC,  
29208, United States

A complex simulation of a rail hub operations is one of the approaches that has been employed by the BNSF Railway to evaluate different expansion scenarios within a rail hub. This study presents few practices to improve the movements of Hostlers in simulation.

#### 56 - The Transport Route Selection of International Container Intermodal Transport Base on the China Railway Express

Bohao Zhao, Southwest Jiaotong University, Chengdu, 611756,  
China

Nippon Express seeks to capitalize on China's Belt and Road Initiative to offer speedy, low-cost transport of containers between Japan and Europe via CHINA RAILWAY Express. The prosperity of CR Express has led to the construction of an international container line which features intermodal transportation. The research conducts a dynamic analysis of this transportation that connects port between Japan Europe from the three perspectives including transport time, total costs and carbon dioxide emissions. This research used Ant Colony Optimization to solve the shortest path model. Using Python and MySQL software to compile routes selection model for international container intermodal transport.

#### 57 - Research on Modularization Design of China Railway Express Freight Product Based on Fuzzy C-means Clustering Algorithm

lv Dong, Southwest Jiaotong University, ChengDu, China,  
YinYing Tang, LuHui Li, Si Chen

By expounding the status quo of the development of China Railway Express freight product and relying on standardized operation procedures, a modular design method for railway freight products is proposed, and pre-segmentation of product modules and product function decomposition are carried out. Then a quantization model of the module division of freight products business, based on fuzzy C-means clustering algorithm is established.

#### 58 - Research on Optimization of Empty Container Allocation in China Railway Express in Case of Chengdu-Europe Express

Xinglong Zhu, Southwest Jiaotong University, Chengdu, 610031,  
China, Yinying Tang, Jingru Ren

In order to reduce the large amount of empty container allocation cost, rental cost and storage cost which are generated during the transportation process of the China Railway Express. This paper analyzes the current empty container transportation of China Railway Express. Considering the factors such as minimum total cost incurred by empty container transportation and meeting customer needs. Establishing China Railway Express empty container allocation model. And Taking Chengdu-Europe Express as an example, and Solved by Lingo software. The result is satisfactory, which provides a reference for the empty container allocation of China Railway Express.

#### 59 - Large Scale Passenger Train Timetabling Using Combined Primal and Dual Approaches

Xuesong Zhou, Arizona State University, Tempe, AZ, 85281,  
United States, Yongxiang Zhang, Qiyuan Peng, Yu Yao

Train timetabling is important for allocating rail network spatial and temporal capacity resources to trains safely and efficiently. This paper proposes a novel fixed-primal-dual (FPD) framework combining the primal and dual approaches. In the FPD framework, the train timetabling process is divided into several stages from the time dimension and the sequences of trains within each stage are generated dynamically considering the primal and dual costs of trains. For each stage, a dynamic programming approach is developed to find feasible space-time shortest paths for the trains sequentially. The benefits of our approach are demonstrated by comparing with previously proposed approaches.

#### 60 - Study on the Matching Method Between Tidal Flow of Passengers and Transport Capacity of Line Network in Urban Railway

Chen Sixia, Southwest Jiaotong University, Chengdu, 610000,  
China, Ma Si, Kuniaki Sasaki

With the rapid development of urban railway in China, operation plan is becoming complicated, and ridership is increasing simultaneously. A serious problem of urban railway network of Chengdu city is that the distribution of passengers is uneven. It will bring waste of transport capacity. Passenger flow will have a distinct phenomenon at peak hours because of commuting passengers. Finding the regular of passenger flow and then finding the sections where are free

and overloaded in network. Big-small Crossroad Method is useful to balance transport capacity and passenger flow. That method means that instead of running the whole line, some trains only runs a part of line.

#### 61 - Feasibility Analysis of the Implementation of a High Speed Rail Line

Reinaldo Crispiniano Garcia, University of Brasilia, 70237-180,  
Brazil, Rodrigo Vigo Groetaers Vianna, Aline Goulart

This work presents a model for the financial analysis of a High Speed Rail Line. It includes economics and social topics besides the need to update the rail cars due to the increase in the demand. Moreover, a case study is presented showing the feasibility of the proposed model.

#### 62 - Analysis on the Development Quality and Scale of Intercity Railway in Yunnan Province

Siyu Tao, Southwest Jiaotong University, Chengdu, China,  
Anjun Li, Zishuai Pang, Tao Feng, Xinmei Chen, Qiyuan Peng

Appropriate railway network means not only to meet the need of travel and development, but also to avoid duplication of investment and waste of resources. Initially, Comparative Analysis and Canonical Correlation Analysis are utilized to estimate the current situation of Yunnan province's railway network. In order to determine a reasonable intercity railway scale, railway network adaptability indicators are integrated to establish a measure model. Meanwhile, referred to similar regional intercity railway projects, the scale of Yunnan provincial intercity railways could be predicted by Linear-regression Analysis. Finally, the development goal of Yunnan intercity railway is put forward.

#### 63 - Research on the Development Patterns of the Urban Functions of The Passenger Transport Hub

Siyu Tao, Southwest Jiaotong University, Chengdu, 610031,  
China, Xinmei Chen, Liwen Wang, Tao Feng, Anjun Li,  
Qiyuan Peng

With the progress of urbanization, green, humane, intelligent and integrated passenger transport hubs are developing. Nowadays, the integrated passenger transport hub is not only planned for transferring, but also providing various urban services. Up to now, the development concept of the urban functions with the traffic station has developed from traditional layout to the mode integrating city and station. Summarize characteristics and adaptability of different modes through the typical cases. The suitable urban function development mode is chosen to guide the transformation and construction of Shapingba integrated hub.

#### 64 - Addressing Orientation-symmetry in the Time Window Assignment Vehicle Routing Problem

Kevin Dalmeijer, Erasmus University Rotterdam, Rotterdam,  
3000 DR, Netherlands, Guy Desaulniers

The Time Window Assignment Vehicle Routing Problem (TWAVRP) is the problem of assigning time windows for delivery before demand volume becomes known. For TWAVRP instances that are difficult to solve by current methods, we observe many similar solutions in which one or more routes have a different orientation, i.e., the clients are visited in the reverse order. We introduce a new branching method that eliminates this orientation-symmetry from the search tree, and we present enhancements to make this method efficient in practice. Through computational experiments, we show that our algorithm outperforms other solution methods, and we solve 29 previously unsolved benchmark instances to optimality.

#### 65 - Real World VRP Needs a GIS

Shubhada Devidas Kshirsagar, Product Engineer, ESRI, Redlands,  
CA, 92373, United States, Heather Moe

The Vehicle Routing Problem (VRP) becomes much more complex when the solutions need to be deployed in the real world. To produce an operational result, the VRP model must include geographically precise inputs. The best way to integrate this massive amount of information is to use a Geographic Information System (GIS) in the problem-solving methodology. This presentation will discuss requirements from a wide range of commercial and public-sector clients over 30 years. With the described GIS inputs, the VRP model will produce a route plan that is both cost efficient and realistic.

#### 66 - Research on Multi-objective Optimization of Multimodal Transportation Routing Choice: Take Chengdu-Lodz Express as an Example

Yang Ge, Southwest Jiaotong University, Chengdu, China,  
Yinying Tang, Qinglin Li, Li Yu

In order to improve the efficiency of CHINA RAILWAY Express, the four indicators of transportation cost, transportation time, transportation quality and international influence are selected as optimization objectives. Considering time window constraints, a multi-objective optimization model for multimodal transport routes is established for designated OD. An improved genetic algorithm is designed to solve the model, and the validity of the model is verified by real data between Chengdu and Lodz. The results show that: transport costs significantly affect the results of the path selection, and the transportation costs restrict the international influence mutually.



#### 67 - Controlling Freeway Merge Operations Under Conventional and Automated Vehicles Traffic

Aschkan Omidvar, University of Florida, Gainesville, FL, 32603  
United States, Mahmoud Pourmehrab, Lily Eleftheriadou

In this paper, we present an optimization algorithm for freeway operations at merge zones which maximizes the average speed of the segment in the presence of Automated Vehicles (AV) and human-operated (i.e., conventional) vehicles. The necessary algorithms are developed to simulate and carry out the merging operations on a 2-lane freeway (one merge line and one ramp line) which is tested under a variety of scenarios ranging in demand level, demand splits, and AV penetration rate. Results suggest that the proposed algorithm can efficiently manage the traffic at freeway merge zones and reduce average total travel time (increase average speed).

#### 68 - Vulnerability Analysis and Assessment of Urban Rail Transit Network

Meiyi Zhao, Southwest Jiaotong University, Chengdu, China,  
Kuniaki Sasaki, Guofang Li, Jianmei Zhu

It is necessary to study vulnerability, what kind of impact the interruption will cause on urban rail transit network, described by the number of passengers multiply time loss, if emergency occurs. First, topological network is built by stations and lines. Then K paths are being searched by GA and their validity judged by time impedance threshold and train schedule. Next, passenger flow will be assigned to multiple paths. Normal distribution is chosen to describe the passenger behavior based on sensitivity to the shortest path and ratio will be corrected according to transfer times. After interruption, passengers were divided into 3 type. 1. all invalid; 2. partly invalid; 3. all valid.

## Tuesday, 12:30PM - 2:30PM

### ■ Tuesday Poster Competition

North Exhibit Hall E

#### Tuesday Poster Competition

Competition Poster Session

Chair: Junming Yin, University of Arizona, Management Information Systems Department, McClelland Hall, Room 430BB, Tucson, AZ, 85721, United States

Co-Chair: Neng Fan, University of Arizona, Tucson, AZ, 85721, United States

Co-Chair: Burcu B. Keskin, University of Alabama, Tuscaloosa, AL, 35406, United States

#### 1 - Smart Additive Manufacturing Using Data Analytics and Feedback Control

Chenang Liu, Virginia Tech, Blacksburg, VA, 24061, United States,  
Zhenyu Kong

A major challenge in additive manufacturing (AM) is to ensure product quality and consistency. To address this challenge, this research proposes an integrated manifold learning algorithm to achieve online quality monitoring and a bilateral time series modeling approach to implement online quality forecasting. With the application of feedback control system, the monitoring and forecasting results are also utilized to achieve significant quality improvement of AM via online process adjustment. The proposed methods demonstrate effective performance in real-world case studies.

#### 2 - Distribution Network Reconfiguration with Decentralized Autonomous Electric Vehicles

Zhaomiao Guo, University of Central Florida, Orlando, FL, 32816, United States

Autonomous electric vehicles (AEVs) provide unique opportunities to cope with the uncertainties of distributed energy generations in distribution network. We investigate the potential benefits of dynamic distribution network reconfiguration (DDNR) considering AEVs' spatial-temporal availability and their charging demand. A mixed integer programming model is proposed to optimally coordinate the charging/discharging of AEVs with DDNR, while satisfying AEVs' original travel plan. Numerical studies show that DDNR and AEV are complemented to each other to improve distribution system operation.

#### 3 - Fireline Construction in a Heterogeneous Forest Landscape

Xu Yang, Northeastern University, Boston, MA, 02115, United States, Emanuel Melachrinoudis

In this research we develop a methodology to construct the fireline in minimum time by considering the realistic case of heterogeneous forest landscape. We represent the forest landscape as a partition into homogeneous areas and consider multiple line segments crossing each polygon that represent potential paths of the fireline. This discretization reduces the forest landscape to a network whose nodes have as attribute the time of the fire arrival. A methodology is developed that uses a modified Dijkstra's algorithm to find the fastest yet safe paths for two

firefighting crews who work simultaneously in two opposite directions until they meet and thus they encircle and contain the fire.

#### 4 - Cell-based Network Flow Model Under Uncertainty in Evacuees' Behavior by Social Influence

Hyeong Suk Na, PhD Candidate, The Pennsylvania State University, University Park, PA, 16802, United States,  
Necdet Serhat Aybat, Soundar Kumara

We investigate a stochastic network flow model for planning a large-scale hurricane evacuation strategy considering uncertainty on the number of vehicles leaving from the affected areas. We model human evacuation behavior using a time inhomogeneous discrete time Markov chain and this corresponds to using a stochastic S-shaped response curve. The proposed model is developed based on the Cell Transmission Model with joint chance constraints and it is handled by the sample average approximation method and Monte Carlo simulation techniques. A numerical case study examines the applicability of the proposed model and the effect of the evacuation traffic flows on different social network topologies.

#### 5 - An Iterative Combinatorial Auction for Fractional Ownership of Autonomous Vehicles

Aigerim Bogrybayeva, University of South Florida, Tampa, FL, 33613, United States, Mahdi Takaloo, Hadi Charkhgard,  
Changhyun Kwon

This study explores a market design for fractional ownership of autonomous vehicles (AVs), where an AV is co-leased by a group of individuals. We propose an iterative combinatorial auction design for this novel application. The study discusses the unique features of the proposed auction and delivers solution tools.

#### 6 - Long Ties Accelerate Realistic Complex Contagions

Amin Rahimian, Postdoctoral Associate, Massachusetts Institute of Technology, Cambridge, MA, 02142, United States, Dean Eckles,  
Elchanan Mossel, Subhabrata Sen

The spread of behaviors (i.e. social contagion) depends on the structure of the network of contacts between people. For simple contagion models borrowed from epidemic spread, highly clustered networks slow spread compared with more random networks, such that interventions that randomly rewire edges would increase spread. However, for other contagion models that require multiple exposures before adoption (i.e. complex contagions), recent work has argued for the opposite conclusion: highly clustered, rather than random, networks facilitate spread. Here we show that slight modifications of prior analyses, which make them more realistic, reverse this result.

#### 7 - Two Stage Stochastic P-Order Conic Mixed Integer Programs Tight Second Stage Formulations

Yingqiu Zhang, Virginia Tech, Blacksburg, VA, 24060, United States

We study two-stage stochastic p-order conic mixed integer programs (TSS-CMIPs) in which the second-stage problems have p-order conic constraints along with integer variables. We provide sufficient conditions under which the integrality constraints on the second-stage integer variables of the TSS-CMIP can be relaxed, without effecting the integrality of the optimal solution of the problem, by adding parametric (non)-linear inequalities a priori. We perform computational experiments to evaluate the effectiveness of this second-stage convexification approach for solving TSS-CMIPs with second-order conic constraints in the second stage.

#### 8 - Operations Research for Blood Donor Management

Nico M. Van Dijk, University of Twente, Enschede, Ph.D.7522 NB, Netherlands

Blood Management is of general societal interest. Dutch blood donations involve 750,000 yearly voluntary donations. By three projects: on blood inventory, on donor delays at collection sites, and on selective donor recruitment, it will be highlighted how Operations Research can provide quantitative and formal support. The results are real-life based on Dutch Blood Supply.

#### 9 - Political Districting with Fairness Objectives: An Optimization-based Framework

Rahul Swamy, University of Illinois at Urbana-Champaign, Urbana, IL, 61801, United States, Douglas M. King,  
Sheldon H. Jacobson

Political districting (PD) is a problem of national interest. Classical models for PD focus on non-political objectives such as compactness. This paper addresses the question: How can voter information (e.g. polling data) be used to find politically fair districts. Three such criteria are used, based on fundamental fairness principles such as proportionality (efficiency gap), partisan (a)symmetry, and competitiveness. A multilevel algorithm reduces instance sizes by graph contraction and solves an exact nonlinear bi-objective problem. A case study in Wisconsin shows Pareto-frontiers between the objectives, and that solutions that are politically fair are still reasonably compact.

### 10 - Optimal Bidding for Highly Valued IT Service Contracts Theoretical Results and Practical Implications

Xiangyu Zhang, Cornell University, Ithaca, NY, 14850,  
United States

Information technology service providers compete to win highly-valued IT service contracts in a tender process. Prior literature shows that features other than price, including the service provider's relationship with the client, contribute to the client's selection because good relationship increases the provider's chance of winning the deal. Thus, it might be beneficial for the provider to lower their price for improving the client relationship and increasing their potential future contracts profits. In this work, we provide theoretical and numerical results illustrating the optimal price is lower than the myopic price which tries to maximize the expected profit of the current deal.

### 11 - A New Collision Avoidance Algorithm for Autonomous Vehicles Considering Physical Constraints

Elnaz Torkamani, Rutgers University-New Brunswick, Piscataway,  
NJ, United States, Zhimin Xi

Vehicle navigation autonomously in a dynamic environment is a challenging task because it should not be pre-programmed under a given handful situations and the vehicle must be able to avoid collisions under numerous unforeseeable but reasonable situations to a human being. From the practical perspective in autonomous cars, the algorithm must be efficient and reliable. This study proposes a new vehicle collision avoidance algorithm for multiple obstacles by eliminating the need of running sampling or optimization approaches, so that the algorithm could be practical useful in real-time collision avoidance under high vehicle speed.

### 12 - Reliability Based Optimal Design of a Microgrid System under Natural Disasters

Zhetao Chen, Rutgers University-New Brunswick, Piscataway, NJ,  
United States, Zhimin Xi

This study proposes reliability-based optimal design of a micro-grid system under service disruptions due to natural disasters. The objective is to determine the minimum number of generators and their distributions in the micro-grid so that the system's recoverability can be guaranteed under random failure scenarios of the power transmission lines. Power flow analysis combining with the Monte Carlo simulation (MCS) are used for uncertainty propagation analysis to quantify the system's recoverability distribution under random failure scenarios of the transmission lines. The proposed work is demonstrated through a 12-bus power system.

### 13 - Characterization of Battery Model Uncertainty for Effective State of Charge Estimation

Modjtaba Dahmardeh, Rutgers University, Piscataway, NJ, United  
States, Zhimin Xi

SOC estimation accuracy of batteries has been extensively studied through the development of various battery models and online dynamic estimation algorithms. All battery models, however, contain inherent model bias due to the simplifications and assumptions, which cannot be effectively addressed by the already established algorithms like EKF. Consequently, as observed in our study, battery SOC estimation using a typical EKF is not very accurate depending on the battery characteristics. This poster reports great potential for improving SOC estimation accuracy by proposing two bias characterization methods (i.e. polynomial and GP regression) without the complexity of novel algorithms.

### 14 - Optimal Smoothed Variable Sample-size Accelerated Proximal Methods

Afrooz Jalilzadeh, Pennsylvania State University, University Park,  
PA, 16801, United States, Uday Shanbhag

We consider a class of structured nonsmooth stochastic convex programs. Traditional stochastic approximation schemes are generally characterized by far poorer convergence rates compared to the deterministic counterparts. In this study, we consider variable sample-size schemes in which the bias in the sampled gradient is reduced by taking increasingly larger sample-sizes. We prove that the deterministic rates can indeed be attained while maintaining an optimal complexity in the number of sampled gradients. Moreover, optimal rates are obtained by combining an iteratively smoothing framework with this variable sample-size structure.

### 15 - Modeling the Impact of Large-scale Disruptions on Supply Chain Networks

Ni Ni, Rensselaer Polytechnic Institute, Troy, NY, 12180,  
United States, Thomas Sharkey

We provide optimization models to capture the impact of disruptions to different segments of supply chains. For disruptions to the production segment, we build two-stage stochastic programming models to optimize the pre-event and post-event strategies in terms of the impact of unmet demand of customers. The insights include a 'chain reaction' among recovery efforts in the production segment. For disruptions to the distribution segment, we create models to predict the cascading failure on supply chains based on damage to infrastructures and restoration models to provide the importance of coordination between efforts for elements in the distribution segment.

### 16 - Lignocellulosic Biomass to Biofuel Supply Chain Optimization with Mobile Densification and Farmers' Choices

Nibal Albashabsheh, Kansas State University, Manhattan, KS,  
66502, United States, Jessica Heier Stamm

We present an optimization model for lignocellulosic biomass-to-biofuel supply chains that considers mobile densification and farmers' choices, factors not considered in prior studies. Case study results based on Kansas data indicate that omitting mobile densification increases logistics costs, and ignoring farmers' choices results in significantly overestimating available supply.

### 17 - OD Flow Prediction with Vehicle Trajectory Data and Semi-supervised Recurrent Neural Network

Yintai Ma, DiDi Research America, Mountain View, CA, 94043,  
United States, Tao Huang, Zhiwei Qin, Jianfeng Zheng

With the emergence of smartphone usage and ride-sharing economy, a large amount of trajectory data of travelers are produced every day, which can be and should be used to leverage the OD flow estimation and prediction on a complex OD network. In this work, We propose a deep neural network to make the prediction of OD flows of an urban network solely based on the trajectory data of DiDi Drivers in both supervised and semi-supervised setting. Our model reaches median MAPE around 25% for peak hours. Our experiments indicate that the app-recorded trajectory data contains essential information of traffic status, encouraging future exploration to use app-recorded trajectory data for traffic patterns studies.

### 18 - Investigating Autonomous Air Operations Centers for On-demand Mobility Networks

Victoria Chibuogu Nneji, PhD Candidate, Duke Robotics,  
Durham, NC, United States

Several manufacturers are developing new vehicles for high-speed intra-city air taxi on-demand mobility (ODM) services. With diverse vehicle design requirements, how might airline operations centers need to innovate to support these new fleet demands? We used task- and time-based data from a collective case study of dispatchers to develop a discrete event simulation to serve as a predictive model of human-system performance in these air operations centers. With this tool, companies can rapidly prototype future ODM concepts of operations to make better informed strategic, tactical, and operational decisions in staffing and designing centers.

### 19 - Reliable Routing of Road-rail Intermodal Freight under Uncertainty

Majbah Uddin, University of South Carolina, Columbia, SC,  
29210, United States, Nathan Huynh

Transportation infrastructures, particularly those supporting intermodal freight, are vulnerable to natural disasters and man-made disasters that could lead to severe service disruptions. These disruptions can drastically degrade the capacity of a transportation mode and consequently have adverse impacts on intermodal freight transport and freight supply chain. To address service disruption, this paper develops a model to reliably route freight in a road-rail intermodal network. The proposed methodology is demonstrated using a real-world intermodal network in the Gulf Coast, Southeastern, and Mid-Atlantic regions of the United States.

## Tuesday, 2:00PM - 3:30PM

### ■ TD01

North Bldg 121A

### Decision Making with Noisy Information

Sponsored: Optimization/Optimization Under Uncertainty

Sponsored Session

Chair: Bo Zeng, University of Pittsburgh, Pittsburgh, PA, 15260,  
United States

### 1 - Incorporating Clustering in Decision Making with Noisy Information

Chaosheng Dong, University of Pittsburgh, 4200 Fifth Avenue,  
Pittsburgh, PA, 15260, United States, Bo Zeng

Clustering is the problem of partitioning unlabeled data points into a number of clusters so that data points within one cluster are homogeneous. In this study, we show that clustering will increase the robustness of the decision made with noisy information. Meanwhile, it will dramatically improve the efficacy of the decision-making process. Numerical results on both synthetic data and real-world problem show the merit of our method.

**2 - Sensor Network Localization Under Imperfect Information**

Liang Xu, University of Pittsburgh, 3700 O'Hara Street, 1048  
Benedum Hall, Pittsburgh, PA, 15261, United States, Bo Zeng

The use of wireless sensors has drastically increased, and accurately estimating the location of sensors under imperfect information becomes more important. In this study, we consider sensor network localization problem through game theory and bilevel generalized interdiction framework. Bilevel optimization models with different distance measures are proposed, and numerical results are also demonstrated.

**3 - Security Games with Multiple Adversaries**

Wei Wang, University of Pittsburgh, 1025 Benedum Hall,  
Pittsburgh, PA, 15261, United States, Bo Zeng

We build a defender-attacker-defender (DAD) model with multiple adversaries, in which different cooperative levels of the attackers are considered. We demonstrate our model on RTS-96 24-bus systems with one and two areas. Computational experiments show that different attackers' collaboration levels have very much different influences on these systems. The results can help allocate defense resources against one group or cooperative adversaries.

**4 - A Study on Approximation Methods of Robust Optimization with Integer Recourse**

Bo Zeng, University of Pittsburgh, 3700 O'Hara Street, Benedum  
Hall, Pittsburgh, PA, 15260, United States

A few approximation strategies are investigated. Numerical results will be presented to evaluate their qualities.

**5 - Traveling Salesman Problem with Probabilistic Visiting Chances Between Nodes**

Yiwen Xu, Assistant Professor, North Dakota State University, 1410  
14th Avenue North, Room 202 Civil & Industrial Engineering,  
Fargo, ND, 58102, United States, saeid rasti

In this talk, we will propose a probabilistic visiting TSP including a success visiting probability from node  $i$  to  $j$ . A chance constraint is added to guarantee that the success probability of the whole travel has a lower bound. Note that this TSP is different from (1) the PTSP proposed by Jaillet in which only a subset of potential nodes needs to be visited, and (2) the VRP with stochastic demand by Bertsimas. All nodes must be visited exactly once. The problem is formulated as an MILP. A PTAS is proposed by a DP algorithm.

**TD02**

North Bldg 121B

**Stochastic Optimization**

Sponsored: Optimization/Optimization Under Uncertainty

Sponsored Session

Chair: Ruediger Schultz, University of Duisburg-Essen, Faculty of  
Mathemati, Thea-Leymann-Str. 9, Essen, D-45127, Germany

**1 - Newsvendor in Sobolev Space - Stochastic Shape Optimization**

Ruediger Schultz, University of Duisburg Essen, Department of  
Mathematics, Thea-Leymann-Str. 9, Essen, D-45127, Germany

The talk reports on some developments in handling shape optimization under uncertainty by means of recourse stochastic programming.

**2 - On Stability of a Risk Averse Linear Bilevel Problem under Stochastic Uncertainty**

Johanna Burtscheidt, University of Duisburg-Essen, Germany

Stochastic bilevel problems arise from the interplay between two decision makers on different levels of hierarchy where the lower level problem is entered by a random vector. We present a risk averse formulation for linear bilevel problems under stochastic uncertainty which are based on special risk measures. In particular, structural properties and qualitative stability of the optimal value function of this model under perturbation of the underlying Borel probability measure will be investigated wrt weak convergence of probability measures. Focusing on a finite number of realizations of an underlying random vector, equivalences to single-level problems conclude the talk.

**TD03**

North Bldg 121C

**Sara Rezaee Vessal Session**

Sponsored: Technology, Innovation Management &  
Entrepreneurship

Sponsored Session

Chair: Antoine Feylessoufi, University of Cambridge, Cambridge, CB2  
3BU, United Kingdom

**1 - The Carrot or the Stick: Quality in Engineering Contracts**

Pascale Crama, Singapore Management University, 50 Stamford  
Road, Singapore, 178899, Singapore, Zhenzhen Chen,  
Wanshan Zhu

In large engineering procurement contracts, the main contractor is responsible for the quality of the end product to the consumer. The main contractor uses subcontractors and the final quality is influenced by the efforts of all the contracting parties. Outcomes that do not meet the minimum required standard require rework, the cost of which is shared between the main contractor and the subcontractor. We find that the first-best may not be attained even for a risk-neutral subcontractor because of the shared rework cost; yet for a risk-averse subcontractor, the main contractor may choose to increase its share of the rework cost.

**2 - Personal Fabrication as an Operational Strategy: Value of Delegating Production to Customer**

Nagarajan Sethuraman, Kenan Flagler Business School, UNC  
Chapel Hill, Campus Box 3490, Chapel Hill, NC, 27599, United  
States, Ali Kemal Parlakturk, Jayashankar M. Swaminathan

In this paper, we study an operational strategy enabled by 3D printing— Personal Fabrication (PF)—in which a firm focuses on product's design and delegates its production to customers. We characterize the conditions under which, such a strategy benefits the firm. We study the implications of various roadblocks for such a strategy: high production costs of 3D printing, intellectual property concerns and product liability issues.

**3 - Technology Adoption in Organisations: An Evolutionary Model**

Antoine Feylessoufi, University of Cambridge,  
St Andrews Street, Cambridge, CB2 3BU, United Kingdom

Through social interactions, the behaviour of an individual is affected by the population but also influences the other members within that population. In a new approach to capture this effect on technology and innovative practices adoption in organisations, we incorporate social comparison into an evolutionary model widely used in biological ecosystems. We find that unexpected and extreme levels of innovative behaviour (or lack thereof) can emerge in organisations through this mechanism. We also find that for a same technology and firm reward mechanism, the culture of the organisation can lead to different adoption patterns.

**TD04**

North Bldg 122A

**Approximation Algorithms**

Sponsored: Optimization/Integer and Discrete Optimization

Sponsored Session

Chair: Xiangkun Shen, University of Michigan, Ann Arbor, MI, 48109,  
United States

**1 - Submodular Optimization with Contention Resolution Extensions**

Benjamin Moseley, Carnegie Mellon University,  
5000 Forbes Av, Pittsburgh, MO, 15208, United States

This talk considers optimizing a submodular function subject to constraints. Previous work usually (1) discovers a fractional solution to the multi-linear extension and (2) rounds this solution to an integral solution via a contention resolution scheme. Diverging from previous work, we introduce a method called contention resolution extensions. A contention resolution extension combines the contention resolution scheme into a continuous extension of a discrete submodular function. In the case where there is loss in both (1) and (2), by optimizing them together, the losses can be combined resulting in an overall improvement.

**2 - Random Sampling and Contraction for Hedge and Hyperedge Connectivity**

Debmalya Panigrahi, Duke University, Durham, NC, United States

In this talk, I will introduce the problem of hedge connectivity which generalizes the notion of (hyper)-edge connectivity in graphs and hypergraphs to model robustness of a network under dependent edge failures. I will then give new algorithms for finding the hedge and hyperedge connectivity of graphs and hypergraphs using random sampling and contraction of hedges and hyperedges.



### 3 - Submodular Maximization Under Matroid Constraints: A Case for Robustness

Alfredo Torrico, Georgia Institute of Technology, Atlanta, GA,  
United States, Mohit Singh, Sebastian Pokutta

In the robust submodular maximization problem subject to a matroid constraint, we are given a collection of  $k$  monotone submodular functions and a matroid on a ground set of size  $n$ . The goal is to select a feasible set that maximizes the minimum of the submodular functions. This is known to be NP-hard to approximate to any polynomial factor. We design a bi-criteria approximation algorithm that returns a set with (nearly) optimal value and such that it is the union of few feasible sets. This algorithm uses less function evaluations than previous works. Also, we provide a computational study of our algorithm in real-world applications.

### 4 - Stochastic Load Balancing on Unrelated Machines

Xiangkun Shen, University of Michigan, 1205 Beal Ave,  
Ann Arbor, MI, 48109, United States, Viswanath Nagarajan,  
Anupam Gupta, Amit Kumar

We consider the unrelated machine scheduling problem when job processing-times are stochastic. We provide the first constant factor approximation algorithm for the setting where one wants a fixed assignment of jobs to machines so as to minimize the expected makespan. The identical machines special case has been well-understood for several years, but the problem was previously open even in the case of related machines. The main technical contribution is an efficiently computable lower bound via an exponential-sized LP, and its rounding.

## TD05

North Bldg 122B

### Linear and Conic Optimization in Energy Systems

Sponsored: Optimization/Linear and Conic Optimization

Sponsored Session

Chair: Alberto J. Lamadrid, Lehigh University, 621 Taylor Street, R451,  
Bethlehem, PA, 18015-3120, United States

### 1 - Multistage Expansion Planning of Distribution Networks Considering Reliability

Javier Contreras, Universidad de Castilla-La Mancha, E.T.S. de  
Ingenieros Industriales, Campus Universitario s/n, Ciudad Real,  
13071, Spain, Gregorio Muñoz-Delgado, Jos M. Arroyo

This work presents the multistage expansion planning problem of a distribution network considering reliability. Thus, the best alternative, location, and installation time for the candidate assets are identified while jointly accounting for economic and reliability aspects. Unlike previously-reported works, reliability is implemented through algebraic expressions whereby the effect of the network topology is explicitly represented by decision variables of the optimization process. The resulting optimization problem is cast as an instance of mixed-integer linear programming.

### 2 - Piecewise Linear Approximation for Separable Concave Programming Problem

Amin Nikakhtar, Texas Tech University, 2500 Broadway,  
Lubbock, TX, 79409, United States, Ismael De-Farias,  
Victoria Howle

Quadratic programming (QP) arises in a wide variety of applications, from finance to public policy and electric grids. We report the results of applying an algorithm that uses piecewise linear functions for approximating QP problems with a separable objective function of multiple variables. We compare our results with the results from three other solvers: CPLEX, BARON, and IPOPT. The results show that the new algorithm outperforms the other three solvers both in computational time and objective function value. It also shows that we can reach a near optimal solution faster than the current solvers.

### 3 - Stochastic Operation for Networked Building Clusters Integrated with Glides and Thermal Storage

Yang Chen, Oak Ridge National Laboratory, Oak Ridge, TN, 37830,  
United States, Patrick O'Connor

The Ground-Level Integrated Diverse Energy Storage (GLIDES) technology is a hybrid pumped hydropower-compressed air technology which can use waste-heat as an energy input. A two-stage stochastic model is established with uncertainties from energy loads and solar radiation for community building clusters equipped with GLIDES and thermal storage and an integer L-shaped algorithm is developed to solve the problem efficiently.

### 4 - Optimal Scheduling for Power Systems Under Uncertainty

Alberto J. Lamadrid, Assistant Professor, Lehigh University, 621  
Taylor Street, R451, Bethlehem, PA, 18015-3120, United States,  
Ray Zimmerman, Carlos Murillo-Sanchez, Haeyong (David) Shin,  
Robert Thomas, Daniel Munoz

We present an open source simulation tool for security-constrained unit commitment (SCUC) problem. We discuss our formulation using a Markov Decision Process with a traditional deterministic approach. We focus on the our proposed stochastic approach to explicitly model of the operational characteristics of the technologies available, the changes over time, the network and congestion effects, and the regulatory constraints that assure reliability and adequacy.

## TD06

North Bldg 122C

### Joint Session OPT/Practice Curated: Recent Advances in Global Optimization and Applications

Sponsored: Optimization/Global Optimization

Sponsored Session

Chair: Erfan Mehmanchi, University of Pittsburgh, Pittsburgh, PA,  
15260, United States

### 1 - Globally Solving Non-convex Quadratic Programs via Linear Integer Programming Techniques

Luis F. Zuluaga, Lehigh University, Harold S. Mohler Laboratory,  
200 West Packer Avenue, Bethlehem, PA, 18015, United States,  
Wei Xia, Juan C. Vera

Quadratic programming (QP) is a well-studied fundamental NP-hard optimization problem which optimizes a quadratic objective over a set of linear constraints. In this paper, we reformulate QPs as a mixed-integer linear problem (MILP). This is done via the reformulation of QP as a linear complementary problem, and the use of binary variables and big-M constraints, to model the complementary constraints. To obtain such reformulation, we show how to impose bounds on the dual variables without eliminating all the (globally) optimal primal solutions; using some fundamental results on the solution of perturbed linear systems.

### 2 - Optimizing a Bundle Pricing Problem

Hamid Nazari, Clemson University, Clemson, SC, 29631,  
United States, Akshay Gupte, Lawrence Joseph McCormick

We are interested in solving a combinatorial matrix assignment problem which appears in literature as a bundle pricing problem in a multi-buyer-single-seller market. The problem has a MIQCQP formulation due to the requirement that a feasible assignment of buyers to bundles have envy-free equilibrium. Literature has many approximation results and polynomial-time algorithms under certain assumptions. We adopt an integer programming approach to solve this problem in general. We test our formulations and polyhedral relaxations on random instances and compare our MIP methodology to the Lagrangian relaxation techniques proposed in literature.

### 3 - Boundedly Rational User Equilibrium Models in Electricity Consumer Market Studies in Smart Grid

Guanxiang Yun, University of Central Florida, 12800 Pegasus  
Drive, P.O. Box 162993, Orlando, FL, 32816, United States,  
Qipeng Zheng

We propose a new boundedly rational user equilibrium (BRUE) model of the residential users' behavior for the consumption of energy schedule with the smart grid. People will accept any option with which utilities just less than a certain level compare to the best option's utility. We also introduce the unit time pricing strategy that can flatten the user's behavior of energy consumption. The problem is solved by using three methods, use BARON directly, penalty method and lagrangian dual method. Even though the BRUE constraints are non-convex constraints, we still find under our conditions, it have the strong duality. From the result, we find by introducing the price, it can decrease the cost of the system.

### 4 - On Robust Fractional 0-1 Programming

Erfan Mehmanchi, University of Pittsburgh, 4200 Fifth Avenue,  
Pittsburgh, PA, 15260, United States, Colin P. Gillen,  
Andres Gomez, Oleg A. Prokopyev

We examine single- and multiple-ratio robust fractional 0-1 programming problems (RFPs) under a broad classes of uncertainty sets. In particular, we demonstrate that under budgeted uncertainty sets single-ratio RFPs are polynomially-solvable if the deterministic counterparts are. We also reformulate the multiple-ratio RFPs as several mixed-integer linear programs (MILPs). Finally, computational experiments are conducted to evaluate the performance of MILP reformulations, as well as to compare the various uncertainty sets.

## ■ TD07

North Bldg 123

**Joint Session OPT/Practice Curated:  
Network Optimization Models and Algorithms for  
Evacuation Planning**

Sponsored: Optimization/Network Optimization

Sponsored Session

Chair: Maxim A. Dulebenets, Florida A&amp;M University-Florida State University, Tallahassee, FL, 32311, United States

**1 - Cost-effective Evacuation Network Design Under  
Travel Congestion**

Nadere Mansouri, Southern Methodist University, Dallas, TX, 75231, United States, Halit Uster

We consider an evacuation network design problem under cost considerations and travel congestion. We propose a mathematical model that prescribes evacuee routes through the road network to shelter locations under evacuation time constraints. To solve our model, we devise an efficient Benders Decomposition framework and present an experimental run on its effectiveness using data from Central Texas. We provide computational results illustrating the efficiency of our solution approach and an analysis of evacuation network design strategies.

**2 - Cell-based Network Flow Model Under Uncertainty Considering  
Social Influence for Large-scale Evacuation**

Hyeon Suk Na, PhD Candidate, The Pennsylvania State University, 234 Leonhard Building, University Park, PA, 16802, United States, Necdet Serhat Aybat, Sukran Ilgin Guler, Soundar Kumara

The emergency management agencies are faced with numerous challenges during the evacuation due to several unpredictable traffic conditions. This study addresses uncertainties of the road capacity induced by traffic congestion in a real evacuation situation. An evacuation network flow model based on the Cell Transmission Model with joint chance constraints is proposed to deal with the uncertainties and the model reliability is investigated. In addition, social media is transforming the way of communicating and sharing the evacuation-related information. A numerical case study examines the applicability of the proposed model and the social media influence for the evacuation process.

**3 - Modeling a Latency Based Evacuation Process**

Hamoud S. Bin Obaid, University of Oklahoma, Norman, OK, 73071, United States, Theodore B. Trafalis

A latency-based evacuation model (LBEM) is developed to optimize the evacuation procedure. The model is composed of two phases. In the first phase, the model builds the feasible space of the time path on every route, then the model uses the feasible space to build the constraints in the second phase as a mixed integer linear programming (MILP) model. The model is capable of capturing the latency of each group of evacuees as the travel time in the model is load-dependent. The evacuees are distributed fairly to balance between system optimum (SO) and user equilibrium (UE). Preliminary computational results are reported.

**4 - Emergency Evacuation Planning Optimization in the Areas with  
Vulnerable Populations**

Maxim A. Dulebenets, Florida A&amp;M University-Florida State University, Tallahassee, FL, 32311, United States, Olumide Abioye, Eren Erman Ozguven, Ren Moses, Walter Boot, Thobias Sando

Many U.S. coastal areas, which are characterized with a significant presence of vulnerable populations (e.g., aging adults), often experience natural hazards. In order to facilitate emergency evacuation planning, this study proposes a set of exact and heuristic algorithms for assigning evacuees to the available evacuation routes and emergency shelters, considering socio-demographic characteristics of evacuees, which may further affect their driving ability. Numerical experiments are conducted to evaluate the proposed solution algorithms using real life emergency evacuation scenarios.

## ■ TD08

North Bldg 124A

**Recent Advances in Optimization Methods for  
Machine Learning**

Sponsored: Optimization/Nonlinear Programming

Sponsored Session

Chair: Lam Minh Nguyen, IBM Thomas J. Watson Research Center, Yorktown Heights, NY, 10598, United States

**1 - Optimal Diminishing Stepsizes in SGD for Strongly Convex  
Objective Functions**

Marten van Dijk, PhD, University of Connecticut, Storrs-Mansfield, CT, 06269, United States

We study the convergence of Stochastic Gradient Descent (SGD) with diminishing stepsize (non-adaptive) in the strong convex case. First, we notice that the Bounded Gradient (BG) assumption is in conflict with strong convexity. Without assuming BG, prior work shows that a diminishing stepsize of  $O(1/t)$  achieves an expected convergence rate of  $O(1/t)$ . Here, we demonstrate a simple example of a strong objective function together with a straightforward proof of a  $O(1/t)$  lower bound on the expected convergence rate (where we do not need a bound on the computed gradients in SGD). The concrete expressions of the upper bound from prior work and this lower bound are about a 32 factor apart for moderate and large  $t$ .

**2 - Catalyst for Gradient-based Nonconvex Optimization**

Courtney Paquette, Lehigh University, 1182 Jaeger St, Columbus, OH, 43206, United States

We introduce a generic scheme to solve nonconvex optimization problems using gradient-based algorithms originally designed for minimizing convex functions. Even though these methods may originally require convexity to operate, the proposed approach allows one to use them without assuming any knowledge about the convexity of the objective. In general, the scheme is guaranteed to produce a stationary point with a worst-case efficiency typical of first-order methods, and when the objective turns out to be convex, it automatically accelerates in the sense of Nesterov and achieves near optimal convergence rate in function values.

**3 - On Linear Convergence for Douglas Rachford Splitting  
and ADMM**

Pontus Giselsson, Lund University, Lund, Sweden

Several local and global linear convergence rate results for ADMM have recently appeared in the literature. Many of these are derived under strong monotonicity and smoothness assumptions. It is well known that ADMM is Douglas-Rachford splitting applied to a Fenchel dual problem formulation. In this talk, we show that the recent linear convergence results for ADMM follow from our results on contraction factors for the Douglas-Rachford operator under similar assumptions. Our analysis improves on previous analyses in three aspects 1) the contraction factors are provably sharp 2) the results hold in more general Hilbert space settings 3) the proofs are more compact as they are based on operator theory.

**4 - Stochastic Quasi Newton Methods – Past, Present, and Future**

Albert Solomon Berahas, Postdoctoral Research Fellow, Northwestern University, 2145 Sheridan Road, C210, Evanston, IL, 60208, United States, Jorge Nocedal, Martin Takac

In this talk, we present a survey of stochastic quasi-Newton (SQN) methods; methods that attempt to judiciously incorporate second-order information using only gradient information and that alleviate some of the problems that plague stochastic first-order methods. We begin with an overview of recent developments of SQN methods, and then describe in detail the multi-batch L-BFGS method and its extensions. We present, in general form, convergence analyses for SQN methods, and illustrate the performance of several SQN methods on a plethora of machine learning tasks. Finally, we discuss open questions and the future of SQN methods.

## ■ TD09

North Bldg 124B

**Optimization for Machine Learning**

Sponsored: Optimization/Nonlinear Programming

Sponsored Session

Chair: Aryan Mokhtari, Massachusetts Institute of Technology, Cambridge, MA, 02139, United States

Chair: Asuman Ozdaglar, Massachusetts Institute of Technology, Cambridge, MA, 02139, United States

**1 - Stochastic Methods for Nonsmooth Nonconvex Optimization**

Damek Davis, Cornell University, 218 Rhodes Hall, Hoy Road, Ithaca, NY, 14850, United States, Dmitriy Drusvyatskiy

We prove that the proximal stochastic subgradient method, applied to a weakly convex problem (i.e. difference of convex function and a quadratic), drives the gradient of the Moreau envelope to zero at the rate  $O(k^{-(1/4)})$ . This class of problems captures a variety of nonsmooth nonconvex formulations, now widespread in data science. As a consequence, we obtain the long-sought convergence rate of the standard projected stochastic gradient method for minimizing a smooth nonconvex function on a closed convex set. In the talk, I will also highlight other stochastic methods for which we can establish similar guarantees.

## 2 - A2BCD an Asynchronous Accelerated Block Coordinate Descent Algorithm with Optimal Complexity

Robert Hannah, UCLA, Los Angeles, CA, 90025, United States, Wotao Yin

In this talk we present work on A2BCD, an asynchronous accelerated randomized coordinate descent algorithm. For asynchronous delays that are not too large, we prove that A2BCD has the same complexity as NU\_ACDM, the current state-of-the-art coordinate descent algorithm. We then show that this complexity is essentially optimal: That is, it cannot be improved except by a small constant factor without very different algorithmic assumptions. To motivate and clarify our proof techniques, we also present an ODE which is the continuous-time limit of our algorithm and converges to a solution at the same rate.

## 3 - Conditional Gradient Methods for Stochastic Submodular Maximization

Hamed Hassani, University of Pennsylvania, 3330 Walnut Street, Philadelphia, PA, 19104, United States

In this talk, we study the problem of constrained and stochastic submodular maximization (both discrete and continuous) and develop gradient methods that achieve a tight approximation guarantee. More precisely, for a monotone and continuous DR-submodular function and subject to a general convex body constraint, we provide stochastic and conditional gradient methods that achieve a  $(1-1/e)$ -OPT guarantee (in expectation). By using stochastic continuous optimization as an interface, we also provide the first  $(1-1/e)$ -OPT tight approximation guarantee for maximizing a monotone but stochastic submodular set function subject to a general matroid constraint.

## 4 - Escaping Saddle Points in Constrained Optimization

Aryan Mokhtari, Massachusetts Institute of Technology, 77 Massachusetts Avenue, Room 32-D608, Cambridge, MA, 02139, United States, Asuman Ozdaglar, Ali Jadbabaie

In this talk, we focus on escaping from saddle points in smooth nonconvex optimization problems subject to a convex set. We propose a generic framework that yields convergence to a second-order stationary point of the problem if the convex set is simple for a quadratic objective function. To be more precise, our results hold if one can find a  $\gamma$ -approximate solution of a quadratic program subject to the convex constraint in polynomial time, where  $\gamma < 1$  is a positive constant that depends on the structure of the convex set.

## TD10

North Bldg 125A

### Joint Session MSOM/RMP/Practice Curated: Online Retailing and Marketplace Analytics

Sponsored: Manufacturing & Service Oper Mgmt  
Sponsored Session

Chair: Yun Fong Lim, Singapore Management University, Singapore, 178899, Singapore

#### 1 - The Impact of Repeat Business and Word of Mouth for an E-Retailer

Opher Baron, University of Toronto, 105 St George Street, Toronto, ON, M5S 1L7, Canada, Simai He, Hongsong Yuan

We use data from the M&SOM data competition to investigate repeat purchase behavior and the impact of word of mouth (WOM) on reference prices at the giant Chinese e-retailer, Taobao. We develop algorithms to study both questions and demonstrate their usage. Our main findings are that improving repeat business is extremely important to Taobao and that it is important to consider WOM affect in the presence of reference price effects.

#### 2 - Urban Consolidation Center or Peer-to-peer Platform? The Solution to Urban Last-mile Delivery

Qiyuan Deng, Singapore Management University, Singapore, Xin Fang, Yun Fong Lim

The growth of last-mile delivery to urban areas creates negative impacts on the environmental, social, and economic well-being of cities. As a potential solution to address this challenge, an urban consolidation center (UCC) bundles shipments from multiple carriers before delivering them to a city center. Despite the potential benefits, the success rate of UCC projects in practice is low. More recently, a notable number of peer-to-peer platforms have been established to share the carriers' truck capacity. These capacity sharing platforms can potentially be more economically sustainable, while making urban last-mile delivery more operationally efficient.

## 3 - Distributionally Robust Inventory Management with Network Flows - An Application to Ecommerce and Omnichannel Retailing

Aravind Govindarajan, Ross School of Business, University of Michigan, Ann Arbor, MI, 48104, United States, Amitabh Sinha, Joline Uichanco

A fundamental assumption in network inventory planning is that the underlying joint distribution of demands across locations is known. However, this may not be the case for ecommerce demand due to high volatility in online customer behavior. We propose a distributionally robust model for network inventory optimization with reactive recourse, where the worst-case expected cost is minimized over the set of demand distributions satisfying known mean and covariance information. We derive closed-form optimal inventory levels and worst-case distribution for two locations and develop tractable upper bounds and heuristic solutions for the multi-location problem.

## 4 - Matching Supply with Demand for Online Retailing

Yun Fong Lim, Singapore Management University, Lee Kong Chian School of Business, Singapore, 178899, Singapore, Song Jiu, Marcus Teck Meng Ang

We consider a joint replenishment, allocation, and fulfillment (JRAF) problem over multiple periods for an online retailer. In each period, the retailer determines the replenishment quantity for each product from each supplier and then allocates the inventory to the FCs. After the demand is realized, the retailer chooses the FCs to satisfy it. The retailer's objective is to minimize the expected total cost. We have developed a two-stage approach based on robust optimization to solve the JRAF problem. A case study with a major apparel online retailer in Asia suggests that the two-stage approach can reduce the retailer's current cost by 36.73%, demonstrating a significant value of joint optimization.

## TD11

North Bldg 125B

### Stochastic Models for Biomanufacturing Supply Chains

Sponsored: Manufacturing & Service Oper Mgmt  
Sponsored Session

Chair: Ananth Krishnamurthy, University of Wisconsin-Madison, Madison, WI, 53706, United States

Co-Chair: Tugce Martagan, Eindhoven University of Technology, Eindhoven, 5611AZ, Netherlands

#### 1 - Contract Structures for Biomanufacturing Projects with Failure Risks

Yasemin Limon, University of Wisconsin-Madison, Madison, WI, 53705, United States, Tugce Martagan, Ananth Krishnamurthy

Bio-pharmaceutical companies often subcontract projects from their drug development pipeline to smaller biomanufacturers to reduce costs of failure. These projects require multiple sequential steps with significant uncertainty, leading to risks of not meeting client requirements. Currently, contract terms for these projects are negotiated with limited quantification of the risks of failure. We analyze the performance of two contract structures, Fee For Service (FFS) and Price Per Mass (PPM) and assess how these contracts distribute profits and costs of failure. We then propose a new Scout Before Commit (SBC) contract, and study when the SBC contract is likely to yield better performance.

#### 2 - Optimal Harvesting and Replenishment Policies to Reduce Changeovers in Fermentation Processes

Yesim Koca, Eindhoven University of Technology, Eindhoven, Netherlands, Tugce Martagan, Lisa M. Maillart, Ivo Adan

We develop a time-based and a condition-based stochastic model to reduce the number of changeovers in the fermentation processes. We determine the optimal harvesting and replenishment policies that maximize the expected total profit obtained from a batch. We analyze the structural characteristics of optimal policies, and illustrate the industry use of the models through a case study.

#### 3 - Biomanufacturing Companies Accelerate Growth Using Operations Research

Ananth Krishnamurthy, University of Wisconsin-Madison, 1513 University Avenue, Madison, WI, 53706, United States, Tugce Martagan, Yasemin Limon

In the biomanufacturing industry, production and planning decisions are challenging due to batch-to-batch variability and uncertainty in the production yield, quality, cost, and lead times. A multidisciplinary team of researchers developed decision support tools that use a data-driven, operations research-based approach to improve biomanufacturing efficiency. Optimization tools for fermentation and purification operations provide a decision support mechanism that links the underlying biological and chemical processes with business risks and financial trade-offs. Interactive scheduling and capacity planning tools enable efficient use of the expensive and limited resources.



#### 4 - Supply Failure Probability in Pharmaceutical Supply Chains under Input-model Uncertainty

Canan Gunes Corlu, Boston University, Alp Akcay,  
Tugce Martagan

We consider a pharmaceutical manufacturer who sources a customized product with unique attributes from a set of unreliable suppliers. We model the likelihood of a supplier to successfully deliver the product via Bayesian logistic regression and study the impact of input uncertainty; i.e., the uncertainty that is due to the estimation of logistic regression parameters from limited amounts of historical data, on the overall supplier failure probability. We investigate how the input-model uncertainty changes with respect to the characteristics of the historical data and the product attributes.

#### ■ TD12

North Bldg 126A

#### Dynamic Decision Making in OM

Sponsored: Manufacturing & Service Oper Mgmt

Sponsored Session

Chair: Hao Zhang, University of British Columbia, Vancouver, BC, V6T 1Z2, Canada

#### 1 - An ADP Approach to Dynamic Matching with Applications in Kidney Exchange

Fan You, University of Colorado-Boulder, 995 Regent Drive,  
Boulder, CO, 80302, United States, Dan Zhang, Doug Popken

We study dynamic matching problems where the objective is to maximize the total matchings over a finite planning horizon with random arrivals and departures. We start by formulating the problem as an MDP, which suffers from the curse of dimensionality. Subsequently, we apply the approximate linear programming approach. We derive an upper bound as well as a control policy from the solution of the ALP, and test numerically on a set of dynamic kidney exchange instances taken from the literature.

#### 2 - Optimizing Remote Maintenance Decisions under Imperfect Failure Predictions

Guanlian Xiao, Eindhoven University of Technology, Eindhoven,  
Netherlands, Alp Akcay, Lisa M. Maillart, Geert-Jan Van Houtum

We consider a critical component which deteriorates according to a three-state discrete time Markov chain, with two unobservable operational states, and a self-announcing failed state. A remote monitoring center periodically receives imperfect signals and suggests maintenance actions to a local service organization. We build a partially observable Markov decision process that takes the binary signals as input, and minimizes the discounted total corrective and preventive maintenance costs. We characterize the optimal policy by at most one critical threshold, and provide a closed-form critical solution. We also show the impact of imperfectness of signals on the objective values.

#### 3 - Analytical Solution to a Partially Observable Machine-Maintenance Problem

Weihua Zhang, University of British Columbia,  
6335 Thunderbird Crescent, Vancouver, BC, V6T 2G9, Canada,  
Hao Zhang

We study a classic machine maintenance problem in which the state of the machine changes according to a hidden Markov process under regular production. The state can be observed upon inspection and can also be reset through replacement. The objective is to find a production-inspection-replacement policy that minimizes the expected discounted cost over an infinite horizon. In contrast to the standard Bayesian framework, we adopt a recently established dual framework to derive an exact, analytical solution to this problem. The solution carries a cyclic structure and highlights the core behavior, which explains the puzzling non-monotone optimal policy widely acknowledged in the literature.

#### 4 - Managing Queues with Static Delivery Guarantees

Mehdi Hosseinabadi Farahani, PhD, The University of Texas at  
Dallas, Richardson, TX, 75080, United States, Milind Dawande,  
Ganesh Janakiraman

We study the problem of managing queues in online food ordering services where customers, who place the order online and pick up at the store, are promised a common due-date lead time. The objective is to minimize the total earliness and tardiness costs incurred by the customers. Due to the difficulty of implementing sophisticated policies in practice, we investigate the performance of easily-applicable heuristic policies. Our results show that a simple policy, that starts serving a customer as soon as the time remaining to the due date falls below a threshold, yields near-optimal solutions.

#### ■ TD13

North Bldg 126B

#### Data-Driven Models in Healthcare

Sponsored: Manufacturing & Service Oper Mgmt/Healthcare  
Operations

Sponsored Session

Chair: Vishal Ahuja, Southern Methodist University, Southern  
Methodist University, Dallas, TX, 75275, United States

#### 1 - Utilizing Data Driven Decision Support Systems to Reduce Readmission Rates for Patients with Congestive Heart Failure

J K. Srinivasan, Boston University, Boston, MA, United States,  
Kellas Ross Cameron

Physicians currently attempt to identify CHF patients that are likely to be readmitted within 30 days. However, the readmission rate for these patients remains over 20%. Data-driven decision support systems can provide an additional tool to understand which patients are at high-risk of readmission. We create a statistical model to utilize patient-specific information to not only more accurately identify the patients most likely to be readmitted, but also why - whether for condition-related reasons or not. This allows physicians to suggest patient-specific readmission prevention strategies.

#### 2 - Being on the Productivity Frontier: Identifying Triple Aim Performance Hospitals

Sriram Venkataraman, University of South Carolina, Department  
of Management Science, Moore School of Business, Columbia, SC,  
29208, United States, Aleda Roth, Anita L. Tucker,  
Jon A. Chlingerian

Hospital decision-makers may face trade-offs that make it difficult to obtain the trifecta of high performance on clinical quality, patient experience, and technical efficiency. Using datasets from 2010 and 2012 and data envelopment analysis, we identify more than 40 triple aim performance hospitals among U.S. acute care hospitals with 200 beds or more. Further, we find that the percentage of physicians employed by the hospital has a positive and significant relationship with triple aim performance, and that bed utilization rate has a positive relationship with technical efficiency but a negative relationship with clinical quality and patient experience performance.

#### 3 - Reduction of Patient and Surgery Preparation Time in the Operating Room

Yann Ferrand, Clemson University, Clemson, SC, United States,  
Brandon Lee, Dee San, Kevin M. Taaffe, Lawrence Fredendall,  
Amin Khoshkenar, Anjali Joseph, Scott Reeves

This paper used a set of cameras to record all the activities in the operating room during 26 surgical procedures and the room preparation periods. Four of these were selected for intensive analysis of the room turnaround and surgery preparation times. All activities by all staff in the room were coded and placed into a Gantt chart format timeline. The timeline was used to identify potential bottleneck resources and how slack resources could begin activities in parallel with the bottleneck resources to reduce the overall length of the turnaround time.

#### 4 - Quality Improvement Spillovers: Evidence from the Hospital Readmissions Reduction Program

Mohamad Soltani, University of Wisconsin-Madison, 4284A, 975  
University Ave., Madison, WI, 53706, United States, Robert Batt,  
Hessam Bavafa

In this study, we look at the impact of the Hospital Readmissions Reduction Program in the US hospitals to examine (1) the extent to which hospitals were able to achieve 30-day readmission reductions for target patients and (2) the extent to which non-target patients experienced "spillover improvements in 30-day readmissions. We also study 31-60-day readmissions and length of stay as possible mechanisms by which hospitals can achieve improvements in 30-day readmissions. Taken together, our results show that this policy has been effective and has generated significant beneficial spillovers in quality improvement.

## ■ TD14

North Bldg 126C

### Queues in Services I

Sponsored: Manufacturing & Service Oper Mgmt/Service Operations

Sponsored Session

Chair: Amy R. Ward, University of Southern California, Los Angeles, CA, 90089-0809, United States

Co-Chair: Rouba Ibrahim, University College London, London, WC1E 6BT, United Kingdom

#### 1 - Large Deviations Analysis for Non-Markovian Multi-server Queues with Abandonments in the QED Regime

David Goldberg, Cornell University, 136 Hoy Road, Ithaca, NY, 14850, United States, Debankur Mukherjee, Yuan Li

We consider the FCFS  $M/H_2/n + M$  queue in the QED regime. It is known that the normalized sequence of steady-state queue-lengths converges to a limit  $W$ , with sub-Gaussian tails. However, the exact tail behavior was left open. Dai and He later conjectured an explicit form for this tail exponent, which was insensitive to higher moments. We explicitly compute the true large deviations exponent, the first such result for non-Markovian queues with abandonments, and resolve the conjecture of Dai and He in the negative. Our stochastic comparison approach sheds light on several novel ways to think about multi-server queues with abandonments, and may be helpful in analyzing other related models.

#### 2 - Workload Management in Telemedical Physician Triage and Other Knowledge-based Service Systems

Soroush Saghafian, Harvard University, Kennedy School of Government, 79 John F. Kennedy Street, Cambridge, MA, 02138, United States, Wallace J. Hopp, Seyed Iravani, Yao Cheng, Daniel Diermeier

Telemedical physician triage (TPT) is an example of a hierarchical knowledgebased service system (HKBS) in which a second level of decision agent (telemedical physician) renders a decision on cases referred to him/her by the primary level agents (triage nurses). Managing the speed-versus-quality trade-off in such systems presents a unique challenge because of the interplay between agent knowledge and flow of work between the two levels. We develop a novel model of agent knowledge based on the beta distribution, and deploy it in a partially observable Markov decision process model to describe the optimal policy for deciding which cases (patients) to refer to the second level for further evaluation.

#### 3 - Operational Issues in Large Jail and Judiciary Systems

Russell Charles Hannigan, University of Chicago Booth School of Business, Chicago, IL, 60615, United States, Baris Ata

We perform an analysis of a large jail and judiciary system with the goal of simultaneously reducing Length of Stay (LOS) and improving outcomes for detainees. Two primary issues contribute to high LOS: a large number of outstanding warrants and detainees' trials often lasting longer than their eventual sentences require. We model the jail as a queueing network and consider the benefits of letting low-level warrants expire. We also consider a dynamic discrete choice model of detainees' behavior to estimate detainees sentence location sensitivity and resulting optimal trial termination time.

#### 4 - The Impact of Customer Impatience on Scheduling in a Multi-class Many-server Queue

Amy R. Ward, University of Southern California, Marshall School of Business, Bridge Hall BRI 401H, Los Angeles, CA, 90089-0809, United States, Amber L. Puha

Many classic models used to study scheduling problems do not incorporate customer impatience. Furthermore, many of the ones that do assume the time a customer is willing to wait for service is exponentially distributed, which can lead to poor scheduling decisions. We study the interplay between customer impatience and scheduling decisions in a many server queue with reneging ( $G/G/N+G$ ) and multiple customer classes. On fluid scale, we characterize a closed-form non-linear relationship between the queue-length and server effort allocation that is determined by the reneging distribution. This leads to an optimization problem whose solution provides insight into scheduling decisions.

## ■ TD15

North Bldg 127A

### Economic Models in OM

Sponsored: Manufacturing & Service Oper Mgmt/Service Operations

Sponsored Session

Chair: Krishnamurthy Iyer, Cornell University, Ithaca, NY, 14850, United States

#### 1 - Diffusion in Random Networks: Impact of Degree Distribution

Scott Rodilitz, Yale University, New Haven, CT, United States, Vahideh Manshadi

Motivated by viral marketing on social networks, we study the diffusion process of a new product on a network where each agent is connected to a random subset of others. The number of contacts (i.e., degree) varies across agents and the firm knows the degree of each agent. Further, the firm can seed a fraction of the population and compensate them on a per-contact basis. Under any bounded degree distribution and for any target adoption proportion, we compute both the cost and the time it takes to reach the target in the limit of network size. Using our limit results, we conduct comparative statics on degree distribution and uncover a trade-off between cost efficiency and fast growth.

#### 2 - Information and Pricing in Unobservable Queues

Guido Martirena, Stanford University, 579 Serra Mall, Stanford, CA, 94305, United States

I consider information and pricing design in unobservable queues with strategic and heterogeneous customers that are privately informed and impatient. I show that 1) if the platform optimizes among all possible pricing and information mechanisms, the optimum is achieved by disclosing all the information about congestion and setting a sequence of posted prices, 2) for any information policy, the steady-state can be replicated by full-information and prices while achieving a higher revenue, 3) I identify conditions under which the platform profits from releasing information strategically and provide a characterization for the optimal rule.

#### 3 - Section 8 Voucher Exchange

Nicholas A. Arnosti, Columbia Business School, 3022 Broadway, Uris Hall, New York, NY, 10027, United States

We consider a dynamic model motivated by the administration of Section 8 vouchers. In the model, family relocation results in inefficient billing between housing authorities. We study the potential for voucher exchange to reduce billing. We show that if the rate at which families become ineligible is identical across cities, then voucher swapping has no long-term effect on the number of voucher recipients living in each city. This implies that either pairwise or multi-way voucher exchange offer a Pareto improvement over current practice. Additionally, we calibrate our model using data from the Twin Cities metropolitan area, and study the magnitude of the benefit of multi-way exchange.

#### 4 - A Truth Serum for Large-scale Evaluations

Vijay Kamble, University of Illinois at Chicago, 405 N. Wabash Ave, Unit 3511, Chicago, IL, 60611, United States, Marn David, Nihar Shah, Abhay Parekh, Kannan Ramchandran

A major challenge in obtaining large-scale evaluations of products or services in online platforms is that of eliciting honest responses from agents in the absence of verifiability. We propose a new reward mechanism with strong incentive properties applicable in a wide variety of such settings. This mechanism has a simple and intuitive output agreement structure: an agent gets a reward only if her response for an evaluation matches that of her peer. But instead of the reward being the same across answers, it is inversely proportional to a popularity index of each answer. Rare agreements earn a higher reward than agreements that are relatively more common.

## ■ TD16

North Bldg 127B

### Sustainable and Socially Responsible Operations

Sponsored: Manufacturing & Service Oper Mgmt/Sustainable Operations

Sponsored Session

Chair: Xin Wang, Hong Kong University of Science and Technology, Hong Kong

#### 1 - Promoting Innovative Technology in Developing Countries through Solution Based Contract

Guangrui Ma, Tianjin University, 92 Weijin Road, 25A, CoME, Tianjin, 300072, China, Ying-Ju Chen, Hau Leung Lee

We study farmers' production decision and technology adoption incentives in developing countries, and then investigate how technology providing firms can use business innovation to promote the technology adoption. We show that through solution based contract, firms can help farmers overcome potential adoption barriers.

#### 2 - To Bribe or Not to Bribe in a Procurement Auction Under Disparate Corruption Pressure

Xiaoshuai Fan, Hong Kong University of Science and Technology, Kowloon, Hong Kong, Ying-Ju Chen, Christopher S. Tang

This paper examines the effect of "disparate corruption pressure on manufacturers' bribery decisions and bidding strategies in a procurement auction. In our setting, small manufacturers are highly likely to be pressed to bribe in exchange for the right of first refusal. We consider the case when only large manufacturer can choose not to bribe. After analyzing a corrupt auction model, we find that the large manufacturer can benefit from corruption even when it is disadvantaged by refusing to bribe. Consequently the large manufacturer has no incentive to expose the collusion between the auctioneer and the small manufacturer, which provides a novel explanation for the prevalence of corrupt auctions.

#### 3 - Social Responsibility Auditing of Supply Chain Networks

Han Zhang, Indiana University Bloomington, 1309 E. 10th St Ste 4100, Bloomington, IN, 47405, United States, Goker Aydin, Rodney Parker

We study a buyer's problem of auditing a three-tier supply network with general sourcing relations between adjacent tiers for social responsibility compliance. The buyer may suffer economic damages if a violation is exposed at a non-compliant supplier. To avoid damages, the buyer may judiciously audit some suppliers; in the event of a failed audit, the buyer decides to either incur a cost to rectify the supplier or drop the supplier from the supply network, losing the potential profit from production attributable to the now-dropped supplier. We characterize the equilibrium of the production activities in the supply network and the buyer's optimal auditing strategies before the production phase.

#### 4 - Green Technology Development and Adoption: Competition, Regulation, and Uncertainty - A Global Game Approach

Xin Wang, Hong Kong University of Science and Technology, IELM, Hong Kong, Soo-Haeng Cho, Alan Scheller-Wolf

When a government is considering tightening a standard on a pollutant, their decision often is influenced by the number of firms being able to meet the tightened standard, because a higher number indicates a more feasible standard. We study how such regulation may affect a firm's incentive to develop a new technology to reduce a pollutant. To analyze this problem, we use the global game framework recently developed in economics. We find that regulation that considers industry capability, compared with regulation that ignores it, can more effectively motivate development of a new green technology. Surprisingly, uncertainty in the payoff can also help promote development of a new green technology.

## ■ TD17

North Bldg 127C

### Joint Session MSOM/Practice Curated: Topics on Two-Sided Platforms

Sponsored: Manufacturing & Service Oper Mgmt/Supply Chain

Sponsored Session

Chair: Fernando Bernstein, Duke University, Durham, NC

#### 1 - The Impact of the Gig-economy on Financial Hardship

Kaitlin Daniels, Washington University in St. Louis, Saint Louis, MO, United States, Michal Grinstein-Weiss

We empirically measure the impact of Uber's entrance into a market on the welfare of workers. Measures of worker welfare considered include income and financial hardship (e.g. failure to pay bills on time). Analysis elucidates the role of gigs like Uber within the broader economy.

#### 2 - Competition Between Two-sided Platforms Under Demand and Supply Congestion Effects

Fernando Bernstein, Duke University, Fuqua School of Business, 100 Fuqua Drive, Durham, NC, 27708-0120, United States, Gregory A. DeCroix, N. Bora Keskin

This paper explores the impact of competition between two ride-sharing platforms. Customers' and drivers' utilities are sensitive to the prices set by the platforms and to congestion in the system. We consider two scenarios, one in which each driver works exclusively for a single platform ("single-homing") and another scenario in which drivers may work for both platforms ("multi-homing" or "multi-apping").

#### 3 - Price, Wage and Fixed Commission in On-demand Matching

Yun Zhou, McMaster University, 1280 Main Street West, Hamilton, ON, L8S 4M4, Canada, Ming Hu

We study an on-demand platform's price and wage determining problem under uncertain market conditions. Demand and supply functions have different forms in different conditions. While the platform can jointly optimize price and wage in each condition, our research shows that the simpler fixed commission structure achieves a decent portion of profit.

## ■ TD18

North Bldg 128A

### Operations/ Marketing Interface II

Contributed Session

Chair: Lifei Sheng, University of Houston-Clear Lake, 2700 Bay Area Boulevard, Houston, TX, 77058, United States

#### 1 - Nonlinear Pricing for Yield Management and Countering Strategic Consumer Behavior

Jing Zhou, Associate Professor, University of North Carolina-Charlotte, 9201 University City Blvd, Belk College of Business, Charlotte, NC, 28223, United States, Moutaz J. Khouja

In this study, we examine the impact of using a nonlinear pricing "buy one at regular price get the second for x% off on the optimal order quantity and the profit of a newsvendor. We also examine the above questions in the presence of strategic consumers. Implementing the nonlinear pricing may increase demand more than by using a straight per-unit discount, and, therefore reduces strategic consumers' chances of obtaining a unit at a discount which decreases their incentive to wait. Thus, this type of discount can be used to counter strategic consumer behavior.

#### 2 - Robust Salesforce Contracts with Inventory Considerations

Xiangyin Kong, Mr, Xi'an Jiaotong University, No. 28, Xian ning Road, Bei ling District, Xi'an City, Shaanxi Province, China, Tat Chee Avenue, Kowloon, Hong Kong SAR, Xi'an, 710049, China Xiangyin Kong, Mr, City University of Hong Kong, Tat Chee Avenue, Kowloon, Hong Kong SAR, Hong Kong, China, Yimin Yu, Gengzhong Feng

We consider the salesforce compensation with limited inventory and model uncertainty where the demand is censored by the lost sales and the parameters of the underlying demand distribution is uncertain. The firm jointly decides the compensation plan and inventory levels by the worst-case criterion subject to the robust incentive compatibility and limited liability condition. We show that a linear contract with commission rates decreasing in inventory is optimal; and that under the optimal robust contract, the firm tends to understock with a multiplicative demand model, contrary to the stock-more effect in the literature; while it can either overstock or understock under a general linear demand.

#### 3 - Free Riding Effect in Sales of a Complex New Product When Multiple Sales People Compete

Vahideh S. Abedi, Assistant Professor, California State University Fullerton, Fullerton, CA, United States, Rahul Bhaskar

Purchase of complex new products (e.g. insurance plans) typically depends on customer word-of-mouth both about the new characteristics of the product and about the quality of service of one or more brokers. We show that this leads to a free-riding effect between the brokers that has not been explored in the literature. We model this sales process, and validate it from membership data for an insurance product. We measure the free-riding effect, and show how the resulting model can facilitate decision making in managing the sales force.

#### 4 - Factors Affecting the Performance of Small And Medium Sized Wholesalers in Korea

Ji Min Park, KyungPook National University, Daegu, Korea, Republic of, Jaewoo Chung

In this study, we analyze the factors affecting repurchase intention in the wholesale industry derived through intensive literature reviews and an exploratory study, which are classified into product, sales competence and service competency. By understanding these factors and their relationships, the authors expect managers in the small and medium wholesale industry will enable more effective management activities.



### 5 - Self Pricing Beating in a Market With Preference Interdependence and Uncertainty

Ting Luo, Assistant Professor, California State University Fullerton,  
Mihaylo College of Business and Economics, Fullerton, CA, 92831,  
United States, Lijia Shi

Self price beating pricing strategy promises the early buyers that if the seller lowers the price in the later period, an ex post price refund that is more than the price difference will be refunded to them. We propose self price beating as a pricing policy under market externality and uncertainty. It combines the advantages of both price commitment and no price commitment. Based on a two-period model, we find that self price beating can sustain the high 1st period demand as price commitment does, while it can also generate high 2nd period profit as in the no price commitment case when there is market uncertainty. The total profit from self price beating surpasses both price commitment and no price commitment.

### 6 - Designing Shipping Policies for Online Retailers: The Role of Topping-up Behavior to Qualify For Free Delivery

Lifei Sheng, Assistant Professor, University of Houston Clear Lake,  
Houston, TX, United States, Guang Li, Dongyuan Zhan

We study a widely used shipping policy for online retailers. Under such a policy, a flat shipping fee can be waived if a customer's total purchase amount in a single order exceeds a certain pre-determined threshold. The threshold may promote some customers to top up their order size to qualify for free shipping. We model this "topping-up" behavior and design the optimal shipping structure under both monopolistic and competitive settings.

## ■ TD19

North Bldg 128B

### Novel Revenue Management Models

Sponsored: Revenue Management & Pricing

Sponsored Session

Chair: Pratik Mital, Revenue Analytics, Atlanta, GA, 30318,  
United States

#### 1 - A Novel Approach for Multiple-round Bid Pricing

Iman Nekooimehr, Revenue Analytics, Atlanta, GA, United States

In B2B pricing, it's very common for the sellers to propose their prices in multiple rounds of bids. The sellers have multiple chances, therefore they can price their products/services higher and gradually decrease their prices in the next rounds of bids. In this presentation, we would like to present a new framework which assists companies find the optimal price when participating in multiple-round bids.

#### 2 - Mathematical Modelling for Time-of-Use Pricing of Electricity in Monopoly and Oligopoly

Goutam Dutta, Professor, Indian Institute of Management, Wing 3,  
Room No 3H, Production Quantitative Methods Area, Ahmedabad,  
Gujarat, 380015, India, Nidhi Kaicker, Debamanyu Das,  
Subhashree Banerjee

This paper attempts to study the efficiency gains for time-of-use (TOU) pricing over flat-rate pricing in the electricity sector. The electricity market may be characterised by a monopoly in some cases, where a single firm continues to enjoy market power, or an oligopoly, where two or more firms compete against one another by strategic interaction. This study establishes the feasibility condition for efficiency gains to arise from time-of-use pricing in a monopolistic set up using constrained optimization. The strategic behaviour of firms in a duopoly, generalizable to  $n$  firms, is modelled in this study using constrained optimization.

#### 3 - Approaches to Cancellation Forecasting in the Travel Industry

John Harvey, Senior Manager, Carnival UK, Southampton,  
United Kingdom

In the Cruise Industry, understanding Cancellation behaviour is key to maximising revenue, as we can identify mitigation strategies as well as overbooking strategies. But new patterns can take time to emerge so relying on previous cancellation curves is insufficient in a dynamic market.

We propose a statistical approach of modelling Cancellations using a Poisson Process at an appropriate level of aggregation. These will allow us to generate confidence intervals and establish the probabilities of a new cancellation trend emerging, which can then be used to update the Poisson models via Bayesian methods.

### 4 - Applications of Mixed-Integer Programming in Media Industry

Oguzhan Ozlu, Revenue Analytics, Atlanta, GA, 30318,  
United States

In this talk, we'll present the applications of mixed-integer optimization models in scheduling television/radio commercials and a high-level architecture of such scheduling solutions. Advertisers purchase several spots to air their commercials for a specified time period. The goal of an ad-scheduling solution is to optimally place all advertisements to maximize the advertiser and broadcaster revenues while minimizing the violations of advertisers' order requirements and reducing the need for manual ad placements by scheduling teams. The ad-scheduling solution automatically retrieves key data inputs from a variety of enterprise data marts, solves a series of interacting MIP's and publishes resulting schedules to the enterprise scheduling system. We will present the challenges and key learnings that helped us to develop automated cloud-based scheduling systems for large media enterprises.

### 5 - Enterprise Revenue Management System

Pratik Mital, Revenue Analytics, Atlanta, GA, 30318, United States

Developing an enterprise revenue management system is a complex task that requires significant resource investment (IT infrastructure and people), and time investment. The task becomes even more complex where entities from different parts of the world are involved and a common platform is being developed to serve all of them. Systems thinking and developing the right team to work on this task is key to its success. This talk will present a case study from developing an enterprise revenue management system for one of the largest cruise companies in the world.

## ■ TD20

North Bldg 129A

### Revenue Management in Advertising

Sponsored: Revenue Management & Pricing

Sponsored Session

Chair: John G. Turner, University of California-Irvine, Irvine, CA,  
92697-3125, United States

#### 1 - Managing Digital Advertising Campaigns

Sami Najafi Asadolahi, Santa Clara University, Leavey School of  
Business, 500 El Camino Real, Lucas Hall, Santa Clara, CA, 95053,  
United States, Naren Agrawal, Stephen A. Smith

Advertising agencies, a key intermediary in the digital advertising supply chain, manage numerous ad campaigns for multiple clients in real-time. Because of uncertainties in the demand from campaigns for viewers, and the rate at which the target viewers visit websites, ensuring that campaigns proceed according to plan is a difficult challenge. We describe a methodology to manage such campaigns.

#### 2 - Dynamic Revenue and Project Management with Application to Online Advertising

Hossein Jahandideh, Google, Mountain View, CA, United States

We consider a provider who makes dynamic pricing decisions for deadline-based projects. The provider has the flexibility of processing a project in different time periods as long as all projects are completed by their respective deadlines. Because of the additional flexibility, this amounts to a non-traditional dynamic network revenue management (DNRM) problem. We convert this problem into the format of a traditional DNRM, approximately solve the problem, and provide a real-time pricing strategy. We discuss the application of this model to online advertising, where advertising campaigns correspond to projects.

#### 3 - Effect of Complex Multimedia Advertising Campaigns: A New Automated Method for Big Data

Will Wei Sun, University of Miami Business School, Miami, FL,  
United States, Pengyuan Wang, Guiyang Xiong, Jian Yang

The proliferation of online advertising not only brings new opportunities for advertisers to reach the consumers but also allows them to efficiently track large-scale individual-level data on ad exposures and conversions. Advertisers often question whether multimedia campaigns are actually effective and it remains unclear how to maximize their success. This study introduces a novel tree-structured causal inference model, which is nonparametric, flexible, computationally efficient, and suitable to analyze complicated nonlinear effects. The model enables automatic segmentation of consumers, allowing advertisers to better optimize the allocation of ad resources via accurate targeting.

#### 4 - Competitive Real-time Policies for the Allocation of Online Display Advertising

Ali Hojjat, University of New Hampshire, 10 Garrison Ave.,  
Durham, NH, 03824, United States, John G. Turner

We propose a new bid scaling mechanism for real-time matching of online guaranteed targeted display advertising with a website's users. Using primal-dual analysis, we derive the competitive ratio and show the conditions under which it beats the commonly known best bound of  $1 - 1/e$ .

## ■ TD21

North Bldg 129B

**Information in Networks**

Sponsored: Revenue Management &amp; Pricing

Sponsored Session

Chair: Ozan Candogan, University of Chicago, Chicago, IL, 27708, United States

**1 - Fake News Propagation and Detection**Yianguos Papanastasiou, University of California Berkeley,  
2220 Piedmont Ave, Berkeley, CA, United States

We consider the problem faced by a social media platform that is observing the sharing actions of a sequence of rational agents and is dynamically choosing whether to conduct an inspection (i.e., a “fact-check”) of an article whose validity is ex ante unknown. We present results pertaining to: (i) the properties of the agents’ sharing behavior; (ii) the structure of the platform’s optimal inspection policy; and (iii) the impact of fake news on the society’s learning environment.

**2 - Fact-checking Policies for Fake Content Detection in Social Networks**Gizem Yilmaz, University of Chicago, 5807 S. Woodlawn Ave,  
Chicago, IL, United States, Ozan Candogan, Varun Gupta

We study the spread of multiple possibly erroneous pieces of content on a network. For a given content the spread rate is time-varying, and the spread process is approximated using an inhomogeneous continuous time branching process. We compute the offspring mean and variance of this branching process and discuss its relationship to the degree distribution of the network. We address the problem of minimizing the total spread of erroneous content, by using simulation techniques together with the moment information of the approximating branching process. We pose the problem as a continuous time optimal control problem and suggest heuristics for an approximate solution.

**3 - An Edge-based Model of Network Formation**Hao Li, Hong Kong University of Science and Technology, Clear  
Water Bay, Academic Building, Room 5551, Kowloon, Hong Kong,  
Ying-Ju Chen, Jin Qi

We present a dynamic model of network formation where new nodes find and connect old nodes based on edges: first, a new node finds an edge purely randomly; second, the new node connects to each endpoint of the selected edges with separated probabilities; third, the new node connects to the out-neighbours of the tail node of the selected edge with a probability. We checked the features of degree distribution and clustering coefficient exhibited by large random networks. Simulations are presented to illustrate the theoretic results of the model. This model could be applied to describe the network where cooperations are formed to produce a masterpiece, e.g. co-authorship network and movie actors network.

**4 - Optimal Signaling of Content Accuracy: Engagement vs. Misinformation**Ozan Candogan, University of Chicago, Booth School of Business,  
Chicago, IL, 27708, United States, Kimon Drakopoulos

We study information design in social networks. We consider a setting, where agents’ actions exhibit positive local network externalities. There is uncertainty about the underlying state of the world, which impacts agents’ payoffs. The platform can choose a signaling mechanism that sends informative signals to agents upon realization of this uncertainty, thereby influencing their actions. We investigate how the platform should design its signaling mechanism to achieve a desired outcome. We discuss our findings in the context of increasing engagement or decreasing misinformation in social networks.

## ■ TD22

North Bldg 130

**Computational Methods in RMP**

Sponsored: Revenue Management &amp; Pricing

Sponsored Session

Chair: Gustavo J. Vulcano, Universidad Torcuato di Tella,  
Universidad Torcuato di Tella, Buenos Aires, 1428, Argentina**1 - Demand Model Estimation with Unobserved Stockouts**Hongzhang Shao, Georgia Institute of Technology, Atlanta, GA,  
United States, Anton J. Kleywegt

In many settings one wants to estimate discrete choice models, but customers’ choice sets are not known. In one such setting stock levels are observed periodically, and stockouts occur between successive observations, with stockout times not being observed. Therefore different customers had different unobserved choice sets. We developed a choice model estimation method that works with data with both unobserved customer arrivals and unobserved stock-outs. We

introduced a transformation of the likelihood function that significantly improved the algorithms’ performance. The method was used to develop a tool for managing vending machines, and results based on these data are presented.

**2 - A Constant-factor Approximation Algorithm for Network Revenue Management**Mika Sumida, Cornell Tech, New York, NY, 10128, United States,  
Yuhang Ma, Paat Rusmevichientong, Huseyin Topaloglu

We provide a constant-factor approximation algorithm for network revenue management problems. In our approximation algorithm, we construct a policy using value function approximations that are expressed as linear combinations of basis functions. We use an efficient backward recursion to compute the coefficients of the basis functions. If each product uses at most  $L$  resources, then the total expected revenue obtained by our policy is at least  $1/(1+L)$  of the optimal total expected revenue. In many network revenue management settings, the number of resources used by a product remains bounded. In this case, our policy provides a constant-factor performance guarantee.

**3 - CDLP-based Bid-prices for Network Revenue Management**Juan Jose Miranda Bront, Universidad Torcuato Di Tella /  
CONICET, School of Business, Av Figueroa Alcorta 7350,  
Buenos Aires, C1428BCW, Argentina, Isabel Mendez-Diaz,  
Gustavo J. Vulcano, Paula Zabala

The primal solution of the linear programming formulation for choice-based revenue management (CDLP) is known to be effective from a revenue perspective. However, from a practical perspective, there is a representation issue since airline systems are in principle incompatible with those offer sets. In this work, we consider a variation of the CDLP that naturally generates bid-prices. Based on our numerical experiments, their performance is promising.

**4 - On Reformulations of Approximate Linear Programs for Network Revenue Management**Jiannan Ke, Shanghai Jiao Tong University, 1954 Huashan Road,  
Zhongyuan 111, Shanghai, 200030, China, Dan Zhang,  
Huan Zheng

Approximate linear programming is a popular method to approximately solve dynamic programs that suffer from the curse of dimensionality. However, approximate linear programs (ALPs) still pose computational challenge due to the large number of variables or constraints. Vossen and Zhang (2015) show that ALPs for the network revenue management problem can be dramatically reduced in size for affine and separable piecewise linear approximations under either independent or discrete choice models of demand. In this paper, we give an alternative proof of the results based on reformulations of constraints in the ALPs and duality arguments. The result also applies to the dynamic pricing setting.

## ■ TD23

North Bldg 131A

**Topics in FinTech and Risk Management**

Sponsored: Finance

Sponsored Session

Chair: Xuedong He, The Chinese University of Hong Kong, Shatin,  
Hong KongCo-Chair: Nan Chen, Chinese University of Hong Kong, Shatin N. T,  
Hong Kong**1 - Risk Adjustment Processes**Sturm Stephan, Worcester Polytechnic Institute (WPI), 100  
Institute Road, Worcester, MA, 01609, United States

In the wake of the financial crisis factors commonly ignored in financial modeling got on the center stage: funding differentials and the absence of the postulated riskfree rate and counter party credit risk. These factors have been taken into account in derivatives pricing in the framework of value adjustments (also known as XVA). However, to the best of our knowledge this has so far not been accounted for in risk management. We are developing a theory of risk-adjustment processes incorporating funding spreads and credit risk to market risk evaluations based on BSDE representations of convex risk measures.

**2 - Evidence from Risk Disclosures: Are Banks Transparent About Their Risks?**Steve Yang, Stevens Institute of Technology, Hoboken, NJ,  
United States, Aparna Gupta, Xiaodi Zhu

We address the risk information transparency of US banks by examining the banks’ risk disclosures in annual reports (10-K) and its relationship with bank risk-taking. We quantify the descriptive using the Sentence-based Dynamic Topic Model and propose an automatic topic labeling algorithm based on a predefined keyword dictionary of 16 risk factors. Comparing the risk factors against the CAMELS risk rating system shows that US banks’ risk disclosures provide useful information pertaining to specific bank risk-taking behavior. Large and small banks differ in emphases, with both lacking disclosing management and liquidity risks.

### 3 - A Confidence Interval-based Learning Algorithm for Stochastic Dynamic Programs and its Applications

Nan Chen, Chinese University of Hong Kong, William M.W. Mong  
Engineering Bldg, Rm 609, Shatin N.T, Hong Kong, Xiang Ma

We employ the information relaxation technique in this paper to develop a method of value iteration to solve stochastic dynamic programs. The advantages of the new method are that we can construct valid confidence interval to assess the performance of a heuristic policy and provide an recursive algorithm to improve the policy quality. Various applications in finance and inventory management are discussed. Our method can also be easily extended to the investigation on reinforcement learning, in which the decision maker has to learn the dynamic of the stochastic system.

### 4 - Bitcoin Transaction Fees

Wei Jiang, National University of Singapore, Singapore, Min Dai,  
Steven Kou, Cong Qin

Although Bitcoin mining activities are widely discussed in the media, as miners attempt to profit from transaction fees, there are few academic papers studying the transaction fees. We proposed a model for Bitcoin transaction fees from the miners' perspective. The model is rich enough to incorporate both inventory and demand levels. The model is calibrated to the empirical data and dynamics of the average transaction fees are discussed. The model is made possible by significantly extending the classical Hotelling model for exhaustible natural resources, via the addition of both feedback supply and an S-shaped stochastic demand function.

## ■ TD24

North Bldg 131B

### Practice- Blockchain and Innovation

Contributed Session

Chair: Qianyu Hu, Penn State University, State College, PA, 16801, United States

#### 1 - Automation and Ecosystem Level Operations Management via Decentralized Ledger Technology

Michael Zargham, CEO, BlockScience, Oakland, CA, 94609, United States, Matthew Barlin

Incentive functions are engineered to induce independent actors to provide services to decentralized networks. Formal models of the system behavior and careful scoping of models based on design goals is paramount. System models may be derived from game theoretic or behavioral economic models; Operations Research and Swarm Robotics provide existing tools for engineering emergent dynamics. Partitioning the problem improves feasibility and introduces testing requirements and integration challenges for simulation and verification. After deployment, systems require tuning capabilities, monitoring, and maintenance. The safety of public economic infrastructure is a duty of engineers.

#### 2 - Blockchain-based Renewable Energy Certificates Program

Fangyuan Zhao, Tsinghua University, Shenzhen, Chinan,  
Ying Kong, Xin Guo

In the era of green energy revolution, distributed renewable energy generation is emerging, while it is out of the scope of conventional renewable energy certificate programs, which involves only large power plants and utility companies. Blockchain shows an advantage of incorporating a galaxy of distributed prosumers in a transparent and low cost manner. This paper proposes a proof of concept model of blockchain-based renewable energy certificates trading system, in which a cryptocurrency is designed for tracing the footprint and stimulating the popularization of renewable energy. The concept model is implemented on Ethereum blockchain for performance and risks analysis.

#### 3 - Blockchain-enabled Pharmaceutical Supply Chain System: A Hyperledger Fabric Design

Qianyu Hu, Penn State University, State College, PA, 16801, United States

The drug supply chain safety has gained immense attention due to prevalent counterfeit products, widespread fake online pharmacies, drug abuse crisis and so on. Serialization, placing unique identifiers on products, can provide some visibility to the pharma supply chain. However, the identifiers suffer from duplicates and are prone to theft. Our blockchain-enabled system keeps the pharma supply chain data in an immutable and distributed manner to enforce zero counterfeits and allows for transparency and accountability. Data stored on the hyperledger fabric system are accessed based on consented permissions to protect users' privacy.

## ■ TD25

North Bldg 131C

### Complex Service

Sponsored: Service Science

Sponsored Session

Chair: Fengming Cui, Tsinghua University, Tsinghua, Beijing, China

#### 1 - The Influence of Water, Sanitation and Hygiene Factors on Healthcare Service Utilization During Floods

Nirarcha Tungtisanont, Assistant Professor, University of Maryland, College Park, 3422 Van Munching Hall, LBPP Dept., College Park, MD, 20742, United States, Aleda Roth

We demonstrate that household level factors associated with access to clean water, sanitation and hygiene (WASH) play an integral role on the over- and under-utilization of healthcare resources during a major flood. We apply econometric analyses using field and archival data from 34,000 households in Thailand during the 2011 flood.

#### 2 - The Impact of Dealer Networks on Market Success of Manufacturers

Sina Golara, Postdoctoral Associate, Massachusetts Institute of Technology, 1 Amherst St., E40, 239C, Cambridge, MA, 02142, United States, Kevin Dooley

Most durable goods manufacturers use a network of dealers to distribute their products. While dealers are the consumer-facing stage of the supply chain and can potentially have a make or break effect on manufacturer's business, the extent of their influence is not very well understood and has been subject to controversy. By scraping web, we obtain daily sales and consumer rating information for all dealerships in the US and all new cars in inventory in five car classes. We find that consumers' satisfaction with dealerships influences their purchase of the product. Furthermore, this effect is stronger in markets where the focal brand's dealer network is sparse and the competing dealer networks are dense.

#### 3 - Performance Effects of Diversity in Experience in Fluid Teams

Antti Tenhi l, IE Business School, Calle Maria de Molina 12, piso 5, Madrid, 28006, Spain, Constantin Alba, Fabrizio Salvador

How does team diversity in past work experience influence project productivity and responsiveness? We study this question using work assignment data from a multinational software services firm. We operationalize diversity in experience along the dimensions of variety of specializations, separation of experience profiles, and disparity of expertise, hypothesizing and observing distinct curvilinear effects for each dimension. We further theorize that team familiarity may moderate these effects, receiving partial support for these hypotheses.

#### 4 - Agent-based Modeling in Complex Service Systems and Service Systems Engineering

Fengming Cui, Tsinghua University, Beijing, China, Lefei Li

We introduce agent-based simulation into the design of complex service systems. Each individual in service processes is modeled as a "smart agent" who interacts with each other. By integrating simulation and service science, we obtain insights about service systems dynamics which help us propose better operation strategies.

## ■ TD26

North Bldg 132A

### AI in Service

Sponsored: Service Science

Sponsored Session

Chair: Ming-Hui Huang, National Taiwan University, Taipei, 10617, Taiwan

#### 1 - Advertising Campaign Optimization

Niloy J. Mukherjee, Research Scientist, Amazon.com, Seattle, WA, United States

Creating an advertising campaign requires several decisions. Including the selection of optimal keywords, match-types and bid values. We discuss methods of making these decisions in an optimal manner when creating a campaign as well as updating them based on performance.



**2 - Waterfall Bandits: Learning to Sell Ads Online**

Zheng Wen, Adobe Systems, 345 Park Avenue, E07-415,  
San Jose, CA, 95110-2704, United States, Branislav Kveton,  
Saied Mehdi, S. Muthukrishnan, Yikun Xian

A popular model of pricing in online advertising uses what is known as the waterfall, where the publisher orders ad networks with their offered prices, and then contacts them in that order sequentially. A common approach to revenue maximization in the waterfall model is to estimate the model from past data and then maximize the revenue in the estimated model. This is statistically inefficient because the learning and optimization are separated. We propose an online learning algorithm for solving this problem, which interleaves learning and optimization. We also derive a sub-linear regret bound for the proposed algorithm, and evaluate it on both synthetic and real-world data.

**3 - Data Scientist Professions in Big Data Era**

Marwah Halwani, King Abdulaziz University, Jeddah, 76208,  
Saudi Arabia, Nicholas Evangelopoulos, Victor Prybutok

With the evolution of technology and big data, industry has adopted new job titles that require a new set of technical skills. This research examines the differences and commonalities among company-posted job requirements for five overlapping job titles, which include statistical analysts, big data analytics professionals, data scientists, data analysts, and business analytics professionals, by obtaining and analyzing online job descriptions through latent semantic analysis. The results are used to clarify skill requirements for big data professionals for the joint benefit of the job market where they will be employed, and academia that prepares such professionals.

**TD27**

North Bldg 132B

**Train the Trainer: Learn How to Bring O.R. to Your Local High School**

Sponsored: Education (INFORMED)

Sponsored Session

Chair: Theresa M. Roeder, San Francisco State University, San Francisco, CA, 94132, United States

**1 - Train the Trainer: Learn How to Bring O.R. to Your Local High School**

Theresa M. Roeder, San Francisco State University, San Francisco State University, San Francisco, CA, 94132, United States

Do you love O.R. and wish you had learned about it sooner? Do you wish you could introduce high school students to the fun math and stats applications our field can provide and answer the perennial question of “when am I ever going to use this”? Come to our Train the Trainer session, where we will provide you a toolkit with everything you need to organize a workshop for high school teachers; the workshop will introduce them to these real-world applications that they can use in their classrooms to engage students.

**TD28**

North Bldg 221A

**Maintenance**

Sponsored: Railway Applications

Sponsored Session

Chair: Nathaniel O. Richmond, BNSF Railway, The Colony, TX, 75056, United States

Co-Chair: Steven Jay Tyber, General Electric, Chicago, IL, 60613, United States

**1 - Predictive Switch Health Using Switch Amperage**

Casey Jen, CSX Corporation, Jacksonville, FL, United States

Among all the Communication and Signal (C&S) components, switches cause biggest number of train delays on line of road. In this study, we leveraged switch amperage and developed a set of classification models to identify switch health. Taking information from multiple data sources, such as switch amperage, switch inspection records, switch incidents records, and many others, these classification models will enable CSX to proactively maintain our vital assets and better plan C&S workforce.

**2 - Predicting Rail Defects with Massive Foot-by-foot Track Geometry Data**

Reza Mohammadi, University at Buffalo, Amherst, NY, United States, Faeze Ghofrani, Qing He

Using foot-by-foot track geometry data, this study examines the relationship between rail defects and track geometry measurements. Fast Fourier Transformation is applied to extract the frequency-domain feature from track geometry data. To identify the significant variables in terms of variation, Singular Vector Decomposition (SVD) is implemented. In fact, SVD is applied to explain the source of variation in the dataset. Studying the behavior of rail defects based on this well-prepared track geometry measurements data set results in time- and cost-effective track predictive maintenance.

**3 - Using Predictive Analytics for Railway Track Maintenance Planning**

Clark Cheng, Sr. Director Operations Res & Chief Data Scientist, Norfolk Southern Corporation, 1200 Peachtree Street NE, Atlanta, GA, 30309, United States, Mabby Amouie, Gongli Duan

Railway track maintenance is critical to safety and efficient operations. It's capital and labor-intensive. The planning process is manual and largely relies on the readings from the most recent single run of track geometry car. In this presentation, we will describe a machine-learning approach to predicting rail wear over five years based on historical track geometry car readings. The rail wear prediction model has significantly improved the track maintenance planning at Norfolk Southern.

**4 - Integrated Optimization of Timetable and Rolling Stock Rescheduling Due to Temporary Maintenance Tasks**

Jianrui Miao, Beijing Jiaotong University, Beijing, China

In daily railway operations, some inevitably unexpected disruptions often occur, resulting in some temporary maintenance tasks arranged, which will perturb normal operations. This paper builds up a space-time-state network based mixed-integer linear programming model to reschedule timetable and rolling stock, i.e. retiming, reordering, re-servicing and re-circulation of rolling stocks, simultaneously. The objective function minimizes total cost of timetable and rolling stock utilization. Finally, comprehensive experiments based on Beijing - Shanghai High-speed Railway Line are conducted to examine the applicability and validity of the proposed method.

**TD29**

North Bldg 221B

**Modeling and Analysis of Emerging Mobility Services and Systems II**

Sponsored: TSL/Urban Transportation

Sponsored Session

Chair: Hai Wang, Singapore Management University, Singapore Management University, Singapore, 178902, Singapore

**1 - Refuse or Accept? Analysis of Taxi Driver Operating Strategies in e-Hailing Platforms**

Debjit Roy, Indian Institute of Management Ahmedabad, Ahmedabad, India, Arulanantha Prabu PM, Prahalad Venkateshan

In e-hailing platforms, a taxi driver adopts one of the three reactive strategies to a customer pick-up request: no refusal, refusal based on proximity, and refusal based on profitability index (based on dry and live-run distance). We develop driver operating policies for profit maximization with different service region topologies.

**2 - On the Range Anxiety for Electric Vehicles: An Empirical Investigation**

Sang Won Kim, CUHK Business School, Hong Kong, China, Ho-Yin Mak, Marcelo Olivares, Ying Rong

One of the most well-cited reasons of slow adoption of electric vehicles is the range anxiety. However, it has not been adequately quantified, quite possibly due to the lack of quality data. We propose a novel way to do so by use of a dataset from a car sharing platform.

**3 - Can Multiple On-demand Service Platforms Coexist?**

Jiaru Bai, Binghamton University, SUNY, Binghamton, NY, 13902, United States, Christopher S. Tang

As venture capital firms are financing many startups that are essentially on-demand service platforms, we wonder how many startups of this kind can survive in a competitive market. To examine this question, we present a model in which two on-demand service platforms compete in both the provider and customer markets with earning-sensitive service providers and price- and delay-sensitive customers.

#### 4 - Public Transit Scheduling Under Ride-hailing Competition and Congestion

Keji Wei, Dartmouth College, Thayer School of Engineering at Dartmouth, 14 Engineering Dr, Hanover, NH, 03755, United States, Vikrant Vaze, Alexandre Jacquillat

Ride-hailing services are becoming increasingly popular in major urban and suburban areas across the world, raising many important questions about their overall impact on the quality of urban transportation and the potential shifting of passengers from public transit to ride-hailing. The objective of this study is to optimize urban public transit schedules while incorporating the impacts of ride-hailing. We present and solve a mixed-integer linear programming model that captures the dynamics between transit schedules, passenger choice, congestion and environmental impacts.

#### 5 - The Logic of Matching in Ride Sharing Markets: Revenues, Service Ratings or Pick-up Times?

Hai Wang, Singapore Management University, Room 5023, School of Information Systems, Singapore Management University, Singapore, 178902, Singapore, Wang Chi Cheung, Guodong Lyu, Chung-Piaw Teo

We study a class of multi-period multi-objective online optimization problems, where a decision maker takes actions over time in an online fashion without being informed of future scenarios. To balance the trade-offs between different objectives, we develop an efficient online policy to derive the “compromise” solution, which minimizes the lp-distance from the attained KPIs to the utopia target. We apply the online policy in ride sharing market settings, and observe that all parties in the ride-sharing eco-system, from drivers, passengers, to the platform, are better off under our proposed online matching policy.

### ■ TD30

North Bldg 221C

#### Communities Towards a Smart City

Emerging Topic: Smart Cities

Emerging Topic Session

Chair: Michael P. Johnson, University of Massachusetts-Boston, 100 Morrissey Blvd., Boston, MA, 02125-3393, United States

#### 1 - Modeling the Role of Human Mobility on Dengue Outbreak Evolution in Sri Lanka

Ying Zhang, Johns Hopkins University, Baltimore, MD, United States, Jefferson Riera, Kayla Ostrow, Sauleh Ahmad Siddiqui, Lauren Gardner

Dengue is a prevalent mosquito-borne disease that infects approximately 390 million people every year globally, particularly in tropical and subtropical countries. There is a need to better understand and predict dengue outbreaks and transmission risk within a region so that vector control and surveillance resources can be optimally targeted. To address this issue, we model the spatial-temporal dynamics of dengue transmission as a function of human mobility patterns, in combination with land use and climate data for the Negombo region in Sri Lanka. We quantify the impact of mobility on disease-spread, and compare it to other standard predictors in the literature.

#### 2 - Community-engaged Planning Support for Shrinking Cities and Blighted Communities

Michael P. Johnson, University of Massachusetts Boston, Department of Public Policy & Public Aff, 100 Morrissey Boulevard, Boston, MA, 02125-3393, United States

In the conversation about smart cities and big data, users have been presumed to be growing, progressive cities seeking to better-manage and better-plan innovative services, as well as tech-savvy residents who want to perform routine tasks more efficiently. Using a review of data and technology applications, research on decision modeling in shrinking cities and novel applications of spatial decision support for neighborhood redesign, I demonstrate how residents of under-developed communities use technology, digital data and decision modeling to make creative and data-informed decisions about the future of their neighborhoods.

#### 3 - A Dynamic Policing Simulation Framework

Khan Md Ariful Haque, The University of Texas at Arlington, Industrial, Manufacturing, & Systems Engr., Campus Box 19017, Arlington, TX, 76019-0017, United States, Victoria C.P. Chen

Predictive policing seeks to predict crime, criminals, and victims. The focus is on prediction itself, as opposed to actions that might mitigate crime. Unfortunately, these predictions are only valid under the same conditions of data collection. Prediction-led policing is a concept that connects police actions to the reduction of criminal activity. This concept recognizes that the policing system is dynamic. For example, criminal behavior will be altered in response to specific actions. The presented framework proposes a structure to study dynamic policing strategies. A case study for the Arlington, TX Police Department is used to illustrate the framework.

#### 4 - Implementing Smart Cities Programs: Towards a New Agenda

Tayo Fabusuyi, PhD, University of Michigan, Ann Arbor, MI, United States

Despite the proliferation of analytics and technological deployments in the urban space, only incremental improvements in performance have been documented. I examine why this is the case and make the argument that the ill-structured nature of the issues at stake; obscure goals from multiple stakeholders and a myriad of poorly understood factors are contributing reasons. Drawing from the policy and community operations research literature, I make the case for a framework that broadens and enriches conventional approaches to capture the subtleties inherent in urban systems. I demonstrate the approach using as a case study the design and implementation of a smart parking program in a mid-size US city.

### ■ TD31

North Bldg 222A

#### TSL Best Thesis Session

Sponsored: Transportation Science & Logistics

Sponsored Session

Chair: Dirk C. Mattfeld, University of Braunschweig, Wirtschaftsinformatik, M hlenpfordtstr. 23, Braunschweig, 38106, Germany

#### 1 - TSL Dissertation Prize

Dirk C. Mattfeld, University of Braunschweig, Wirtschaftsinformatik, Myhlenpfordtstr. 23, Braunschweig, 38106, Germany

The TSL Dissertation Prize is the oldest and most prestigious honor for doctoral dissertations in the transportation science and logistics area. The following criteria is used in judging candidate dissertations: i) Fundamental contribution and originality of the ideas or methods, ii) Practical importance or applicability in solving important real problems, and iii) Clarity and excellence of the exposition.

### ■ TD32

North Bldg 222B

#### Vehicle Routing I

Sponsored: TSL/Freight Transportation & Logistics

Sponsored Session

Chair: Camilo Ortiz-Astorquiza, Université de Montréal, Montreal, QC, H3E 1C6, Canada

#### 1 - Robust Optimization of Heterogeneous Vehicle Routing Problems Under Demand Uncertainty

Anirudh Subramanyam, Carnegie Mellon University, DH3122, 5000 Forbes Ave., Pittsburgh, PA, 15213, United States, Panagiotis Petros Repoussis, Chrysanthos Gounaris

The Heterogeneous Vehicle Routing Problem (HVRP) generalizes the classical VRP to allow multiple vehicle types, with different capacities, fixed and variable costs. In this work, we study a generic HVRP under demand uncertainty. First, we develop robust versions of classical local search moves. Specifically, we augment local search so that the generated vehicle routes remain capacity-feasible for demand realizations from any of five broad classes of uncertainty sets. The robustified local search is shown to be modular via two metaheuristic implementations. Second, we develop a new integer programming formulation to obtain lower bounds and quantify the quality of the metaheuristic solutions.

#### 2 - The Inventory Routing Problem with Time Windows

Gizem Ozbaygin, Sabanci University, Faculty of Engineering and Natural Sciences, Istanbul, 34956, Turkey, Esra Koca, Hande Yaman

In this study, we consider the inventory routing problem with time windows (IRPTW), which is a variant of the vehicle routing problem with time windows involving inventory management decisions over a discrete planning horizon. More precisely, the inventory level at each retailer is managed by the vendor, who plans the distribution routes in a way that the retailers never run out of stock and are served within their specified time windows. We propose an exact solution approach for the IRPTW and report the results of our preliminary experiments.

### 3 - The Locomotive Assignment Problem with Distributed Power

Camilo Ortiz-Astorquiza, Université de Montréal, Montreal, QC, Canada, Emma Frejinger, Jean-François Cordeau

The Locomotive Assignment Problem consists of determining the optimal assignment of locomotive types to scheduled trains while ensuring power requirements and flow balance. We introduce a variant of the LAP where the operation mode of the train is also part of the decision process. Two modes of operation are considered: Distributed Power and Conventional. We also include additional constraints and preferences to capture the requirements of the partner railway company for this project, Canadian National Railway (CN). We model the problem as a network design problem, present an IP formulation and discuss a solution method with some preliminary computational results.

## ■ TD33

North Bldg 222C

### Design and Modeling of Advanced Manufacturing

Emerging Topic: OR and Advanced Manufacturing

Emerging Topic Session

Chair: Linkan Bian, Mississippi State University, MS, 39762, United States

#### 1 - Life Cycle Cost Trade-off Model: Comparison of Life Expectancy and Quality on Overall Cost

Janis Terpenney, Penn State University, Industrial & Manufacturing Engineering, 310 Leonard Building, University Park, PA, 16802, United States, Connor Jennings

The classic problem in business is the trade-off between quality and cost. Models have been created to predict the life expectancy of products based on usage and manufacturing specifications and other models have been created to estimate the total life cycle cost of the model. However, few models look at both life cycle length and life cycle cost together. This paper presents a framework that combines these two types of models to determine an optimal decision. A Genetic optimization algorithm is applied to find the minimal cost, given a desired life cycle. An alternative model is also presented, that determines the maximum life cycle, given a set cost.

#### 2 - A Design and Process Improvement Framework for Additive Manufacturing

Gul Kremer, Iowa State University, 2529 Union Drive, 3004 Black, Ames, IA, 50011, United States

Although additive manufacturing (AM) offers unprecedented opportunities to design and manufacturing professionals to improve product designs and benchmark manufacturing processes for capability comparisons, the cost of training and technology for AM adoption is high. Specifically, AM adoption as a viable alternative requires part designs that take into account technology capabilities and limitations. Moreover, what is possible with a specific technology using one material may not be possible with another material. Finally, reproducibility is a significant concern across many AM technologies that requires attention. This talk will summarize our group's work responding to these challenges. The design and process improvement framework synergistically uses Axiomatic Design, TRIZ, Design of Experiments and Process Capability Analysis. Several case studies will be summarized that show tangible benefits of using the developed framework.

#### 3 - A Spare Parts Sourcing Policy with Additive Manufacturing

Taner Cokyasar, University of Tennessee-Knoxville, Knoxville, TN, United States, Mingzhou Jin, Sean Willems

Spare part demand is usually met through two suppliers: fast and slow. The trade-off in between these channels was extensively studied in the literature. In recent studies, additive manufacturing (AM), was proposed as an alternative option to minimize spare parts acquisition cost. Yet, these studies did not quantitatively measure the effectiveness of the technology. In this study, an optimization model was developed to assess the viability of acquiring AM technology and determine the sourcing policy of the parts. M/G/k queueing theory and (S-1, S) inventory policy were used to calculate the average long-term cost of using AM and inventory options, respectively.

#### 4 - Layer-wise Quality Modeling of Laser-Based Additive Manufacturing Using High-Dimensional Thermal Images

Linkan Bian, Mississippi State University, Industrial and Systems Engineering Department, MS, 39762, United States, Wenmeng Tian, Seyyed Hadi Seifi Shishavan, Hongyue Sun

One of the main challenges in Additive Manufacturing (AM) process is concerned with functional quality of fabricated parts. A novel layer-based approach is introduced to evaluate the quality of the deposited layer based on analyzing the process properties (e.g. thermal history). High dimensional process data is mapped to a lower dimensional domain that is correlated to the porosity distribution of a layer. A real-world case study shows that the accuracy of the proposed methodology in predicting defected layers is close to 98%.

## ■ TD34

North Bldg 223

2:00 - 2:45 Simio/

2:45 - 3:30 Provalis Research

Emerging Topic: Technology Tutorials

Emerging Topic Session

#### 1 - Simulation and Scheduling Software All in One!

Renee Thiesing, Simio LLC, 3616 Wynbrooke Circle, Louisville, KY, 40241, United States, Katie Prochaska

Simio is a premier simulation and scheduling software that allows you to expand traditional benefits of simulation to improve daily operations. In this tutorial, we will demonstrate Simio's 3D rapid modeling capability to effectively solve real problems. Explore how a single tool can be used to not only optimize your system design, but also provide effective planning and scheduling. Come explore the Simio difference and see why so many professional and novice simulationists are changing to Simio.

#### 2 - The Different Text Analytics Approaches used for Business Analytics

Normand Peladeau, Provalis Research, Montreal, QC, Canada

Text analytics can provide you with real value by helping you quickly extract meaningful information from your text data such as incident reports, corporate reports, social media, customer reviews and much more. However, Text Analytics doesn't work the same way for everyone. To make text analytics work for you, you need to know some of the pitfalls to avoid the pitfalls. We will show you techniques and methods you can deploy, what's behind them and what to watch out for.

## ■ TD35

North Bldg 224A

### Traffic Flow Management Concepts

Sponsored: Aviation Applications

Sponsored Session

Chair: James Calvin Jones, University of Maryland-College Park, Cambridge, MA, 02140, United States

#### 1 - Autonomous Air Traffic Control for Sequencing and Separation with Nested Deep Reinforcement Learning

Marc Brittain, Iowa State University, Ames, IA, United States, Peng Wei

With the increasing air traffic density and complexity in the traditionally controlled airspace, an autonomous air traffic control system is needed as the ultimate solution to handle dense, complex air traffic. In this work, we design and build an artificial intelligence agent to perform air traffic control sequencing and separation. The approach is to formulate this problem as a reinforcement learning model and solve it using deep reinforcement learning. For demonstration, the NASA Sector 33 app has been used as our learning environment for the agent. Results show that this agent can guide aircraft safely and efficiently through Sector 33 and achieve required separation at the metering fix.

#### 2 - Saturation Technique for Optimizing Planned Acceptance Rates in Traffic Management Initiatives

Peng Wei, Assistant Professor, Iowa State University, Aerospace Engineering Department, Iowa State University, Ames, IA, 50011, United States

In this paper, we have addressed a fundamental question in TMI PAR planning: do there exist optimal PARs which only depend on the physical airport or airspace capacity but not the demand? We show that this conjecture holds true in the deterministic capacity case but not in the general stochastic case. We propose a new heuristic saturation technique. We demonstrate that this technique can not only reveal the properties and limiting behaviors of GDP models but also could potentially be used as a robust PAR policy when facing demand uncertainty. The findings of this paper provide valuable insights in understanding the TMI rate planning problem and a robust algorithm for GDP optimization.

#### 3 - Reinforcement Learning Methods for AFP selection

James Calvin Jones, University of Maryland-College Park, Cambridge, MA, 02140, United States

In this talk we discuss the use of a set of reinforcement learning algorithms for setting the planned flow rates on a set of airspace flow programs. The work is validated through the use of an agent-based air traffic management simulation.



## ■ TD36

North Bldg 224B

### Robotics, Drones, and AVs in Logistics

Emerging Topic: Robotics, Drones and Autonomous Vehicles in Logistics

Emerging Topic Session

Chair: Michael Levin

#### 1 - Unmanned Aerial Vehicle Path Planning for Network State Estimation

Cesar N. Yahia, The University of Texas at Austin, Austin, TX, 78705, United States, Stephen D. Boyles, Christian G. Claudel

We investigate the problem of planning a trajectory for an unmanned aerial vehicle with the objective of estimating network state parameters. The optimal trajectory would maximize the information on the network state over a finite time horizon. In this case, planning and estimation are coupled since different paths chosen by the mobile sensor generate distinct observations, which in turn directly influences the quality of the estimates. To address this problem, we propose an online control algorithm based on forward propagation of traffic flow.

#### 2 - Traffic Optimization for a Mixture of Self-interested and Compliant Agents

Michael Albert, University of Virginia, Charlottesville, VA, United States, Guni Sharon, Peter Stone, Stephen D. Boyles, Tarun Rambha

This paper focuses on two commonly used path assignment policies for agents traversing a congested network: self-interested routing, and system-optimum routing. A computationally tractable method is presented that computes the minimal amount of agents that the system manager needs to influence (compliant agents) in order to achieve system optimal performance. Moreover, this methodology can also determine whether a given set of compliant agents is sufficient to achieve system optimum and compute the optimal route assignment for the compliant agents to do so. Experimental results are presented also presented.

#### 3 - Who Should Drive? Optimal Switching Policy Between Driving Entities in Semi-Autonomous Vehicles

Franco van Wyk, University of Tennessee, Knoxville, TN, United States, Anahita Khojandi, Neda Masoud

Autonomous vehicles are expected to increase safety on the road. However, currently automated entities do not necessarily outperform human drivers under all circumstances. Therefore, in certain conditions it is safer for the human driver to take over the control of the vehicle. However, switching control back and forth between the driver and the automated driving-entity may itself pose a short-term, elevated risk. We develop a Markov decision process model to determine the optimal driving-entity switching policy that minimizes the expected safety risk of a trip, considering the dynamic changes of the road/environment during the trip. We conduct numerical analyses and provide insights.

#### 4 - Leveraging Shared Autonomous Electric Vehicles for First/last Mile Mobility

T. Donna Chen, Assistant Professor, University of Virginia, P.O. Box 400742, Charlottesville, VA, 22904, United States, Farhan Javed

A simulation framework is proposed to evaluate shared autonomous electric vehicle (SAEV) operations that center around Tukwila light rail station to provide first/last-mile mobility in Seattle. Results show great potential for leveraging SAEVs to increasing the station's catchment area, resulting in reduced parking demand. The proposed SAEV fleet reduce system-wide VMT by 36.65% through ridesharing. Fast charging technology decreases the fleet size and wait time by 56% and 72.97%, respectively. Decision makers can apply this framework to evaluate the service by comparing scenarios with varying vehicle configuration, capacity, and charging infrastructure.

## ■ TD37

North Bldg 225A

### Large-Scale Games

Sponsored: Applied Probability

Sponsored Session

Chair: Gabriel Weintraub, Stanford Graduate School of Business, Stanford, CA, 94304, United States

#### 1 - Mean Field Equilibria for Resource Competition in Spatial Settings

Krishnamurthy Iyer, Cornell University, Ithaca, NY, 14850, United States, Pu Yang, Peter Frazier

Inspired by crowd-sourced transportation services and other location-based activities, we consider a model of competition among nomadic agents for time-varying and location-specific resources. Each agent derives a periodic reward based on the overall resource level at her location, and the number of other

agents there. Each agent is free to move between locations, and at each time decides whether to stay at the same location or switch to another one. We study the equilibrium behavior of the agents as a function of dynamics of the stochastic resource process and the nature of resource sharing in the limit where the number of agents and locations increase proportionally.

#### 2 - Mean Field Equilibrium: Uniqueness, Existence, Comparative Statics, and Applications

Bar Light, Stanford GSB, Stanford, CA, United States, Gabriel Weintraub

The standard solution concept for stochastic games is Markov perfect equilibria (MPE), but the computation of MPE becomes intractable as the number of players increases. We instead consider mean field equilibria (MFE) that have been popularized in the recent literature. We make three main contributions. First, our main result in the paper provides conditions that ensure the uniqueness of an MFE. Second, we generalize previous existence results of an MFE. Third, we provide general comparative statics results. We apply our results to dynamic oligopoly models commonly used in previous work. We believe our uniqueness result is the first of its nature in the class of models we study.

#### 3 - The Cutoff Structure of Top Trading Cycles in School Choice

Irene Yuan Lo, Columbia University, New York, NY, United States

The prominent Top Trading Cycles (TTC) mechanism has attractive properties for school choice, as it is strategy-proof and Pareto efficient. However, these properties are obfuscated by the common combinatorial description of TTC. We show that the TTC assignment can be described by admission cutoffs for each pair of schools. In a large-scale continuum model these cutoffs can be computed directly from the distribution of preferences and priorities, providing a framework for evaluating policy choices. As an application of the model we solve for optimal investment in school quality under choice and find that an egalitarian distribution can be more efficient as it promotes better sorting by students.

#### 4 - The Ubiquity of Aggregate Uncertainty in Mean Field Equilibria

Daniel Lacker, Columbia University, 500 W. 120th St, Mudd 306, NY, United States

A game with a continuum of agents is typically justified by showing that, if the mean field (continuum) game has a unique equilibrium, then any sequence of equilibria in the corresponding N-player games converges as N goes to infinity to this mean field equilibrium (MFE). For static games, even when the MFE is not unique, limit points of N-player games can still be characterized as mixtures (randomizations) over the set of MFE. However, in dynamic games with nonunique MFE, there are other randomized limit points which cannot be described as mixtures of MFE; the relevant aggregate quantities evolve stochastically. The goal of this talk is to explain this phenomenon and provide examples.

## ■ TD38

North Bldg 225B

### Design Innovations in Matching Markets and Systems

Sponsored: Applied Probability

Sponsored Session

Chair: Vahideh Manshadi, Yale University, New Haven, CT, 06511, United States

#### 1 - Carta: A Data-driven Course Planning Platform

Ramesh Johari, Stanford University, Huang Engineering Center Rm 311, 475 Via Ortega, Stanford, CA, 94305-4121, United States, Sorathan Chaturapruek, Thomas Dee, Rene Kizilcec, Mitchell Stevens

College students rely on increasingly data-rich environments when making learning-relevant decisions about the courses they take and their expected time commitments. In this talk we discuss recent research involving Carta, a course exploration platform for undergraduates. In particular, we discuss two field experiments that investigate the consequences of such a platform on college students' GPA.

#### 2 - On the Optimal Design of a Bipartite Matching System

Rene A. Caldentey, The University of Chicago, Booth School of Business, 5807 S. Woodlawn Ave, Chicago, IL, 60637, United States, Philipp Afeche, Varun Gupta

In this talk, we explore the optimal design of matching topologies for a multi-class multi-server queueing system in which each customer class has a specific preference over server types. We investigate the performance of the system from the perspective of a central planner who must decide the set of feasible customer-server pairs that can be matched together under fairness constraints for both customers and servers.

### 3 - Joint Pricing and Matching in Ridesharing Systems

Erhun Ozkan, Koç University, Istanbul, Turkey

Two key questions common to all ridesharing firms concern pricing and matching. The pricing decisions determine both customer demand and driver supply. The decision of which driver to match to an arriving customer determines how long that customer must wait for driver pick-up. We study the interplay between the pricing and the matching decisions of a ridesharing firm. We show that optimizing only in the pricing (matching) dimension while using same area matchings (constant prices) has no benefit to the firm. Therefore, pricing and matching decisions should be optimized jointly.

### 4 - On Matching and Thickness in Heterogeneous Dynamic Markets

Vahideh Manshadi, Yale University, New Haven, CT, 06511, United States, Itai Ashlagi, Maximilien Burq, Patrick Jaillet

We study dynamic matching in an infinite-horizon stochastic market. While all agents are potentially compatible with each other, some are hard-to-match and others are easy-to-match. Agents prefer to be matched as soon as possible and matches are formed either bilaterally or indirectly through chains. We adopt an asymptotic approach and compute tight bounds on the limit of waiting time of agents under myopic policies that differ in matching technology and prioritization.

## ■ TD39

North Bldg 226A

### Queueing and Inventory Models

Sponsored: Applied Probability

Sponsored Session

Chair: John Hasenbein, University of Texas-Austin, Austin, TX, 78712-0292, United States

#### 1 - Stochastic Analysis of Queues with Information Updates

Jamol Pender, Cornell University, 228 Rhodes Hall, Ithaca, NY, 14850, United States

Many service systems provide real-time information to their customers with the goal of reducing the customers' anxiety of the unknown. However, the information might be unreliable and is often not given in real-time. In this talk, we will show how to prove fluid limit theorems for a state dependent infinite server queueing model where customers choose which queue to join by a generalized customer choice model. In the choice model, the information about the queue length is updated in discrete intervals unlike a constant delay model. We show that the fluid limit is given by a system of functional differential equations with a non-stationary time delay.

#### 2 - Queue Length Asymptotics for the G/G/D Queue with Heavy-tailed Service Times

Chang-Han Rhee, Centrum Wiskunde and Informatica, Jakoba Mulderplein 164, Amsterdam, 1018 MZ, Netherlands, Mihail Bazhba, Jose Blanchet, Bert Zwart

In this talk, we answer the long-standing open question posed by Sergey Foss and Ward Whitt regarding the queue length asymptotics of the multiple-server queues with heavy-tailed service times. It is well documented that queueing systems typically experience congestions because of a small number of exceptionally large jobs in heavy-tailed environments. However, the rigorous characterization of such phenomenon has been limited to power-law type service times. In this talk, we show that when the service time distribution has a Weibull tail, a number of unexpected and interesting features—such as the asymmetry in job sizes and the trade-off between the number of big jobs and their sizes—arise.

#### 3 - Optimal Stock Allocation for Production-inventory Systems with Multiple Impatient Customer Classes

Yasar Levent Kocaga, Sy Syms School of Business, Belfer Hall Room # 403/A, 2495 Amsterdam Ave, New York, NY, 10033, United States, Yen-Ming Lee

We address the production and inventory control of a make-to-stock system with multiple impatient customer classes. We assume Poisson demand and exponential production times. Demand not satisfied immediately is backordered; but waits only up to an exponentially distributed amount of time and is cancelled if not satisfied within this time. We show that the threshold inventory rationing policy, which is optimal under backordering and lost sales, is still optimal under certain conditions including a requirement on the order of order cancellation rates.

#### 4 - A Unified Fluid Model for Service Systems with Exogenous and Endogenous Dependencies

Chenguang (Allen) Wu, Hong Kong University of Science and Technology, Clear Water Bay, Hong Kong, Achal Bassamboo, Ohad Perry

A prevalent assumption in the queueing literature is that the service times of customers are independent of the system's state, and of all other primitives comprising the system. However, in many practical settings, the service requirements of arriving customers may depend on their individual patience times, or on the delay they experienced while waiting to be served. We thus

consider two models, corresponding to the two dependence structures, to which we refer as exogenous and endogenous dependence. To approximate the intractable queueing processes, we propose a unified fluid approximation which captures two models simultaneously while exposes fundamental differences between the two models.

## ■ TD40

North Bldg 226B

### Spatial Decision Analysis

Sponsored: Decision Analysis

Sponsored Session

Chair: Valentina Ferretti

#### 1 - Persistent Patterns of Discriminatory Housing Policy and Inequity: A Spatial Statistical Analysis

Anna White, University of Michigan, Ann Arbor, MI, United States, Seth Guikema

Racial discrimination by housing and lending institutions was legal and widely practiced well into the 1960s in the United States. Although such discrimination is now illegal, the footprint of the system can be visualized through discriminatory "redlining maps created by the Home Owner's Loan Corporation (HOLC). We use Bayesian Belief Networks and statistical methods to analyze the relationships between maps created by the HOLC and current day quality-of-life indicators like health, income, employment, and education in cities across the United States. Through this analysis, we reveal the patterns that endure across the country as a result of this system.

#### 2 - Weight Elicitation for Spatial Decision Problems

Jay Simon, American University, 4400 Massachusetts Avenue, NW, Washington, DC, 20016, United States

Decisions with spatial outcomes present several preference assessment challenges. Some can be addressed via preference conditions that make the functional forms of value and utility functions simpler. Others, however, are unavoidable; if an outcome will occur across a large geographic space, then it is necessary to elicit a large number of weights from stakeholders. We present a fast and cognitively simple weight approximation technique for a large number of regions, and show that it performs well relative to commonly used approaches.

#### 3 - Cognitive Biases in Spatial Decision Analysis

Valentina Ferretti, London School of Economics and Political Science, Houghton Street London WC2A 2AE, London, United Kingdom

The need and interest to consider cognitive and motivational biases has been recognized in different disciplines (e.g. economics, decision theory, finance, risk analysis) and has recently reached environmental decision making. Within this domain, Spatial Decision Analysis represents a particularly interesting domain to explore new dimensions and implications of behavioral aspects. This talk will present insights from a first behavioral experiment on the spatial dimension of biases. The aim of the experiment is to understand whether or not and to which extent the use of spatial information (maps) can bias the weights' elicitation phase of a Multicriteria Decision Aiding process.

## ■ TD41

North Bldg 226C

### Cyber Risk and Public Policy

Sponsored: Decision Analysis

Sponsored Session

Chair: Jonathan W Welburn, RAND Corporation, Pittsburgh, PA, 15213, United States

#### 1 - Text Mining and Public Policy

Seifu John Chonde, Penn State University, Alexandria, VA, 22314-2299, United States

RAND is devoted to helping the public and clients understand the impact of policies. Over the past few years, RAND has developed a suite of text analysis tools known as RAND-Lex that have been applied to a variety of different types of texts. This talk will overview a subset of research projects that RAND has completed to demonstrate the ongoing issues faced in text mining. For example, recent work has shown the utility of embedding models in natural language tasks such as sentiment analysis and document classification; however, the bias of these models is largely unknown and is an ongoing area of research complicating the use of these models for certain applications.

## 2 - The Cyber Threat and Options For Deterrence

Jonathan W. Welburn, RAND Corporation, 4570 Fifth Ave #600,  
Mailstop 3, Pittsburgh, PA, 15213, United States

The risk of cyberattacks on critical infrastructure has materialized beyond science fiction. The realistic threat of attacks on the power grid underscores the need for novel policy actions that deter adversaries and enhance resilience. We model the potential impact of cyberattacks on the grid, highlighting economic consequences and strategies for deterrence.

## 3 - Frameworks for Cybersecurity are Failing

Igor Mikolic-Torreira, PhD, RAND Corporation, Arlington, VA,  
United States

Effective cybersecurity can be attained by creating financial incentives for manufacturers to produce secure technologies, or from legal frameworks that protect users and set standards for vendors. Based on four role-playing exercises we conducted in the U.S. and Australia during the past two years with over 200 participants, we find that both models are failing: existing financial incentives for security are insufficient at best, and society has not implemented a regulatory model for cybersecurity. Our approach also served to illuminate the cybersecurity interests and priorities of governments, the business community, private organizations, and individuals; helped us understand the roles of these various groups in cybersecurity; and set the stage for us to explore how legal, economic, and societal mechanisms might be harnessed to advance cybersecurity.

## 4 - Targets and Attackers: Cybersecurity and Commercial UAVs

Katharina Ley Best, The RAND Corporation, 5836 Ferree Street,  
Pittsburgh, PA, 15217-1452, United States

RAND will discuss a framework for assessing cybersecurity risks related to increased adoption of commercial UAVs by government/law enforcement, adversaries, and civilians. The framework helps policymakers identify and think about risk related to cybersecurity and UAVs, covering cases where UAVs are cybersecurity targets as well as cases where UAVs are serving as cybersecurity weapons. In building the framework, we use a variety of methods, including the STRIDE threat model and the cyber kill chain, to understand and inventory the UAS/cybersecurity threat space. We include a review of attacks, introduce key industry trends that affect the complexity of the UAV and cybersecurity landscape, and highlight implications for policymakers.

## ■ TD42

North Bldg 227A

### Mining Data for Business Intelligence

Sponsored: Analytics

Sponsored Session

Chair: Davit Khachatryan, Babson College, 231 Forest St, Babson Park,  
MA, 02457, United States

## 1 - Uncovering Insight from Patent Data using Text Mining

Davit Khachatryan, Babson College, Babson Park, MA, 02021,  
United States, Brigitte Muehlmann

In 1790 President George Washington signed a bill launching a framework which over decades evolved into the modern patent system in the United States. Today the United States Patent and Trademark Office receives more than half a million patent applications annually. In this talk, I will provide a background on patenting and discuss a recent project that involves text mining of patents related to cybersecurity. I will discuss how topic modeling and in particular Latent Dirichlet Allocation (LDA) can be used to define a measure for assessing the alignment between patent claims and specification. I will then illustrate how the newly defined measure can be of value to entrepreneurs and patent examiners.

## 2 - Relieving Emergency Room Overcrowding through Data Modeling

Courtney Paulson, Assistant Professor, University of Maryland,  
College Park, MD, 20742, United States

Maryland has the longest ER wait times in the nation primarily due to ER overcrowding. In partnership with the University of MD Medical Center, we explore several interventions to alleviate hospital patient pressures. One (Mobile Integrated Healthcare) is designed to provide effective, efficient care outside the hospital. Paramedics and nurses with advanced training assist identified patients off-site. We also consider in-house practices like stationing physical therapists in the ER to reduce wait times for consultations. We show this can result in significant decreases in ER length of stay.

## 3 - Realizing the Commercial Value of Healthcare Innovation

Dessislava Pachamanova, Babson College, Math/Science Dept,  
319 Babson Hall, Babson Park, MA, 02457, United States,  
Sinan Erzurumlu

We develop a framework for identifying factors that contribute to the commercial value of innovations. We illustrate the approach on data from a large healthcare provider, and discuss strategic implications of the findings.

## 4 - Are Major Airlines Losing the Battle? Investigation of Contrasting Market Domination Strategies

Farbod Farhadi, Roger Williams University, 1 Old Ferry Road,  
Bristol, RI, 02809, United States, Amirhossein Alamdar Yazdi

There has been substantial research on competition between legacy and low cost airlines in the US domestic passenger market. This competition mainly takes place in the medium haul and short haul flights. However, the nature of competition in these markets are substantially different. In this study we demonstrate the contrasting strategies of legacy airlines in these two market types, and investigate the domination rules in a 10-year panel of US domestic air transport data.

## 5 - Health Care Process Mining for Hospital Workflow Improvements

Ranjith Tellis, Philips Research North America, Cambridge, MA,  
United States, Michael Prokle, Jevita Poer, Ushanandini Raghavan,  
Christopher Hall, Sandeep Dalal, Prabhakar Dixit

The switch to value-based reimbursement drives health care leaders to further explore innovative ways to reduce costs while keeping patient and staff satisfaction at the highest possible level. New and available data sources are combined to propel innovative solutions for clinical decision-making. Taking an operational view in hospital workflow, we highlight key insights and learning from mining health care data for modeling, simulating, and optimizing of a Boston area interventional radiology department. We discuss how process mining, simulation, and optimization can be integrated for quick decision-making and present multiple practical use cases with actionable case study results.

## ■ TD43

North Bldg 227B

### Informing Energy Technology Commercialization through Systems Analysis

Emerging Topic: Energy and Climate

Emerging Topic Session

Chair: Daniel Sanchez, American Association for the Advancement of  
Science, Washington, DC, United States

## 1 - Near-term Deployment of Carbon Capture and Sequestration from Biorefineries in the United States

Daniel Sanchez, University of California-Berkeley, Berkeley, CA,  
United States

Capture and permanent geologic sequestration of biogenic CO<sub>2</sub> emissions may provide critical flexibility in ambitious climate change mitigation. However, most bioenergy with carbon capture and sequestration (BECCS) technologies are technically immature or commercially unavailable. Here, we evaluate low-cost, commercially ready CO<sub>2</sub> capture opportunities for existing ethanol biorefineries in the United States. The analysis combines process engineering, spatial optimization, and lifecycle assessment to consider the technical, economic, and institutional feasibility of near-term carbon capture and sequestration (CCS).

## 2 - City-Integrated Renewable Energy for Sustainable and Resilient Power Systems

Deborah Sunter, UC Berkeley, Berkeley, CA, United States

To prepare for an urban influx of 2.5 billion people by 2050, it is critical to create cities that are low carbon, resilient, and livable. We explore options for establishing sustainable urban energy systems by reducing and shifting energy consumption, particularly in the buildings and transportation sectors, and providing robust, decentralized, and renewable energy sources. Through technical advancements in power density, city-integrated renewable energy will be better suited to satisfy the high-energy demands of growing urban areas.

## 3 - The Role of Technology Innovation in Methane Emissions Mitigation Policy

Arvind P. Ravikumar, Stanford University, Stanford, CA, United  
States

Rapid development in unconventional oil and gas resources have raised concerns regarding associated methane emissions. Methane, a highly potent greenhouse gas, contributes about 25% to anthropogenic global warming. Because of low gas prices, solutions to detect and repair methane emissions needs to be cost-effective. In this talk, I will discuss new technological approaches such as truck-, drone-, and plane-based systems to rapidly detect methane emissions at oil and gas facilities. Using techno-economic modeling, I describe how such innovative approaches can be incorporated within a policy framework to achieve cost-effective emissions mitigation.



#### 4 - Geospatial Analysis of the Near-term Potential for Carbon Negative Bioenergy in the United States and Pathways of Meeting the Potential

Ejeong Baik, Stanford University, Stanford, CA, United States,  
Daniel Sanchez, Peter A. Turner, Katharine J. Mach,  
Christopher B. Field, Sally M. Benson

Bioenergy with carbon capture and storage (BECCS) is a negative emissions technology that may play a crucial role in climate change mitigation. However, the near-term deployment potential of BECCS is limited by the ability to transport biomass and CO<sub>2</sub>. A high resolution geospatial analysis is conducted to determine the near-term potential of BECCS in the U.S. by considering the colocation of biomass production and suitable storage sites. The analysis shows that 30% of the available biomass in the U.S. in 2020 is collocated with a storage site, and the resulting near-term potential is 100 Mt CO<sub>2</sub>/yr. The study helps define opportunities that minimize the social and economic barriers to BECCS deployment.

## ■ TD44

North Bldg 227C

### Panel Discussion on Grand Challenges for Energy Systems

Sponsored: Energy, Natural Res & the Environment/Electricity

Sponsored Session

Chair: Kory Hedman

Co-Chair: Javad Lavaei, University of California-Berkeley, Berkeley, CA, 94720, United States

#### 1 - The Need for Better Software to Solve Power Systems Optimization Problems

Richard O'Neill, Federal Energy Regulatory Commission,  
Silver Spring, MD, USA.

For over a century, power system optimization has suffered from approximations due to the need for a good, but not optimal solution in a specific time frame. We will review the approximations in current use and what needs to be done to improve both the formulation and solutions. We will discuss the potential payoffs for improvements.

#### 2- Computational Challenges For Power Grid Resiliency

Jean-Paul Watson, Sandia National Laboratories, 7305 Blue  
Cypress Avenue NE, Albuquerque, NM, 87113-2065, United States

Solving power grid resiliency problems pose computational challenges that are distinct from those traditionally associated with traditional reliability-focused operations paradigms. We will survey work and open challenges in this key emerging area, emphasizing data science issues that must be solved prior to deployment of any computational resiliency approaches.

#### 3 - The Evolution of Power Systems Needs

Jessica Harrison, MISO, Carmel, IN, USA.

The power industry is undergoing significant changes, with an increase in digitalization, decentralization and de-marginalization. This presentation will briefly review these trends and then identify what challenges and opportunities they present for the power sector. Particular attention will be given to wholesale markets and the choices and needs wholesale markets and their members face in light of these changes.

#### 4 - Energy Systems Challenges and Overview of Arpa-E

Kory W. Hedman, Program Director, Advanced Research Projects  
Agency-Energy U.S. Dept. of Energy, Washington, DC,  
United States

#### Panelists

Richard O'Neill  
Jessica Harrison

## ■ TD45

North Bldg 228A

### Joint Session ENRE/Practice Curated: One and Two-level Equilibrium Modeling with Applications in Energy II

Sponsored: Energy, Natural Res & the Environment/Electricity

Sponsored Session

Chair: Steven A. Gabriel, University of Maryland, College Park, MD, 20742-3021, United States

Co-Chair: Benjamin Field Hobbs, Johns Hopkins University, Baltimore, MD, 21218, United States

#### 1 - Multi-objective Infrastructure Investment Under Uncertainty

Verena Hagspiel, PhD, NTNU, Norway, Maria Lavrutich

We study optimal infrastructure investment decisions of a social planner (SP) that has to anticipate capacity investment of a private company (PC) in a market characterized by uncertain demand. The proposed model captures the investment decisions of the SP and PC and accounts for the conflicting objectives and game-theoretic interactions of the distinct agents. Taking an option-based approach allows us to study the effect of uncertainty on the investment decisions, and to take the agents' discretion over investment timing as well as size into account. We show, if and how the SP can align the decision of the PC with the social optimum using the fact that the PC is dependent on the infrastructure provided.

#### 2 - Bi-level Transmission Planning with Imperfect Transmission and Distribution Charges

Pengcheng Ding, Johns Hopkins University,  
3400 North Charles Street, Baltimore, MD, 21218, United States,  
Benjamin Field Hobbs

Transmission network cost recovery is an important issue in part since network charges affect incentives concerning bulk generation investment mix. Investment decisions can be further affected by distributed energy resources' participation in the market, either in front of or behind the meter, which is also affected by network cost recovery. These interactions are usually neglected in proactive transmission planning. We assume perfect coordination between transmission and distribution network planners, and investigate: how generation and DER decisions would be affected by alternative network cost recovery methods, and how a proactive transmission planner can consider those reactions.

#### 3 - Discretely Constrained Mixed Complementary Problems - Application and Analysis of a Stylized Electricity Market

Richard Johannes Weinhold, TU Berlin, Berlin, Germany

This paper provides insight into different areas of DC-MCPs. First, we look at three different solution-methods for DC-MCPs from the literature and compare them in terms of solutions and usability. The methods discussed in this paper use disjunctive constraints, special ordered sets of type 1 (SOS1) and an implementation of a certain median function. The different methods are applied to a stylized electricity market including a minimum-generation constraint. The minimum-generation constraint includes binary variables, making the problem a DC-MCP.

## ■ TD46

North Bldg 228B

### Integration of Electric Vehicles in Power Grid

Sponsored: Energy, Natural Res & the Environment/Energy

Sponsored Session

Chair: Vignesh Subramanian, Tampa, FL, 33617, United States

Co-Chair: Tapas K. Das, University of South Florida, Tampa, FL, 33620-5350, United States

#### 1 - Siting Charging Stations for a Growing Electric Vehicle Fleet

Mustafa Lokhandwala, Purdue University, West Lafayette, IN, 47906, United States, Hua Cai

While more cities are setting goals for electric vehicle (EV) penetration, the growing EV fleet will require the support of additional charging infrastructures. The charging infrastructure development is a path dependent process in which the city can choose from upgrading the existing charging stations or investing in new ones. The locations and the type of the charging stations can influence the EV system's electricity demand load profile. This study uses an agent-based model to analyze the optimal charging infrastructure expansion strategies. The emerging travel pattern changes (e.g., ride sharing) and their impacts on the charging station siting are also evaluated.

#### 2 - Solar Powered Bidirectional Smart Charging of EVs with V2G and Regulation Services

Mahdi Kefayati, Electric Power Engineers, Inc., 13001 Highway  
71, Suite G100, Austin, TX, 78738, United States,  
Gautham Ram Chandra Mouli, Ross Baldick, Pavol Bauer

We present an Integrated PV Inverter and EV Charger module that exploits the time and space synergies between the PV generation and demand for EV charging as well as market prices for energy and reserves to offer an economic, efficient and scalable solution for transportation electrification. The optimal operation of the module, formulated as a MILP is also presented. Finally, simulation results are demonstrated and discussed.

### 3 - On The Fairness and Stability of Aggregator-guided Demand Response Programs

Kevin Melendez, University of South Florida, Tampa, FL, 33613, United States, Tapas K. Das

The cooperation among demand side players in the electricity market is a recent subject of interest. In this paper, cooperation among the load consuming entities (LCEs) managed by a demand response aggregator (DRA) is studied. A decision making model for the DRA is proposed with three alternative objectives: (1) overall community cost minimization solution, (2) the Nash bargaining solution and (3) the solution with minimum distance from the ideal point. The modeling approaches were tested using ERCOT (recent) historical data and the three objectives were compared and contrasted under different problem scenarios.

### 4 - A Two-layer Robust Optimization Model for Dynamic Pricing of Electricity and Demand Response by Electric Vehicle Aggregators

Vignesh Subramanian, University of South Florida, Tampa, FL, 33617, United States, Tapas K. Das

This paper develops a robust two-layer bilevel optimization model for obtaining hourly nodal dynamic prices (DP) and corresponding demand response (DR) by electric vehicle (EV) aggregators. The top layer determines the day-ahead quantities and prices. The bottom layer models the real-time (RT) operations and formulates it as a bilevel program; at the upper-level system operator determines dynamic prices and in the lower level aggregators optimize EV consumption. Results demonstrate the feasibility of DP & DR actions even under RT price uncertainties.

## ■ TD47

North Bldg 229A

### Stochastic Gradient Descent: Recent Trends

Emerging Topic Session

Chair: John Shortle, George Mason University, Dept of Systems Engineering & OR, 4400 University Drive MS 4A6, Fairfax, VA, 22030-4444, United States

#### 1 - Stochastic Gradient Descent: Recent Trends

Raghu Pasupathy, Purdue University, Department of Statistics, 150 N. University Street, West Lafayette, IN, 47907, United States, Farzad Yousefian, David Newton

Stochastic Gradient Descent (SGD), also known as stochastic approximation, refers to certain iterative structures used for solving stochastic optimization and root finding problems. Owing to several factors, SGD has become the leading method to solve optimization problems arising within large-scale machine learning and "big data contexts such as classification and regression. This tutorial will cover the basics of SGD with an emphasis on modern developments. The tutorial starts with examples and problem variations where SGD is applicable, and then details important flavors of SGD that are currently in use. The presentation of this tutorial will include numerical examples.

## ■ TD48

North Bldg 229B

### Sustainability and Social Responsibility

Sponsored: Energy, Natural Res & the Environment Environment & Sustainability

Sponsored Session

Chair: Chengzhang Li, Purdue University, West Lafayette, IN, United States

#### 1 - Choosing the Contract Terms in Carbon Offset Markets

Gokce Esenduran, Purdue University, 403 W. State Street, West Lafayette, IN, 47907, United States

Purchasing voluntary carbon offsets is becoming an increasingly popular way of counteracting carbon emissions. One of the main issues with carbon markets is additionality, i.e., whether the offset project would have happened even if it were not funded through this market. Offset providers can prove additionality through contract terms, i.e., by forward crediting of ex-ante offsets. Or, providers can choose prompt delivery of existing offsets and ensure risk-free deliveries. We analyze the competition between providers and find the equilibrium choice of contract terms. We identify under what conditions prompt delivery achieves higher expected emission reduction than forward crediting.

### 2 - Mitigating Poverty through Solar Panel Adoption in Developing Economies

Zhuo Feng, Assistant Professor, Dalian University of Technology, No. 2 Linggong Road, Dalian, 116024, China, Qiaochu He, Guangrui Ma

In this paper, we investigate a national strategy initiated by the Chinese governments, to combine the growth of solar energy sector with poverty mitigation. By considering households' strategic behavior in buying/selling electricity, we show that only a subset of households will adopt solar panels in equilibrium. We have also examined the government's optimal subsidy design to achieve socially optimal adoption number. Since many Chinese local governments have introduced Public Private Partnership (PPP) scheme to encourage solar panel adoption, we have further examined the outcomes of PPP scheme.

### 3 - Can Voluntary Time-of-use Tariffs be Successfully Diffused in the Residential Electricity Sector?

Karthik Murali, University of Alabama, Tuscaloosa, 351 Alston Hall, Tuscaloosa, AL, 35487, United States, Dong Gu Choi, Michael Lim, Valerie Thomas

Time-of-use pricing is increasingly deployed with some success in the industrial sector, but uptake among residential consumers remains sluggish. In this paper, we investigate how heterogeneity in consumer use-preferences complicates the problem of designing an optimal voluntary time-of-use pricing scheme, and suggest alternative mechanisms to improve residential consumer participation.

### 4 - The Value of Competition in Remanufacturing

Narendra Singh, Indian School of Business, Knowledge City, Sector 81, SAS Nagar, Mohali, 140 306, India, Karthik Ramachandran, Ravi Subramanian

We study an OEM's product strategy when the OEM offers a new product that depreciates over time and consumers are strategic. The OEM competes with a third-party remanufacturer for acquisition and remanufacturing of the depreciated products. We study how competition from the third-party remanufacturer affects the OEM.

### 5 - Ensuring Corporate Social Responsibility in Supply Chain Networks through Multi-unit Bargaining

Chengzhang Li, Purdue University, West Lafayette, IN, 47906, United States, Qi Feng, Mengshi Lu, J. George Shanthikumar

We study ensuring corporate social responsibility (CSR) in general supply chain networks through multi-unit bargaining. We derive the equilibrium negotiation outcome, which captures the imbalance of the bargaining power in the supply chain, and demonstrate its advantages over existing approaches. We also investigate the initiator's preferred implementation structure, and various extensions including multiple investment levels, multiple CSR programs, and decentralized implementation structure decisions that recover the initiator's preferred one.

## ■ TD49

North Bldg 230

### Renewables, PHEVs, and Electricity Markets

Emerging Topic: Energy and Climate

Emerging Topic Session

Chair: Yongpei Guan, University of Florida, Gainesville, FL, 32611, United States

#### 1 - Capacity vs Energy Subsidies for Renewables: Simulation of the 2030 EU Power Market

Benjamin Field Hobbs, Johns Hopkins University, Ames Hall 3rd Fl Geography & Enviro, 3400 N. Charles St, Baltimore, MD, 21218, United States, Ozge Ozdemir, Marit van Hout, Paul Koutstaal

We compare the impact of energy-focused (feed-in premium) and capacity-focused (investment subsidies) renewable policies upon the EU-wide electric power market in 2030 using a market equilibrium model COMPETES. Specifically, do capacity-based policies result in significantly more investment and possibly learning? We also evaluate the efficiency of national policy targets for renewable electricity production (as a whole or per technology) and compare these with a cost-effective allocation of renewable energy production, given resource quality, network constraints and the structure of the electricity system in the various EU countries.

## 2 - How Sampling and Averaging Historical Solar and Wind Data Distorts Generation Expansion Planning

Cynthia D. Bothwell, Johns Hopkins University, Baltimore, MD, 21286, United States, Benjamin Field Hobbs

Industry practice includes developing typical load shapes to forecast future system requirements. As weather-dependent wind and solar generation increase, the prediction of their contribution to the system has also relied on averaging techniques that disregard correlations of load and renewable output. Using long-term optimized expansion planning including hourly dispatch, this work shows the pitfalls of data averaging ignoring dependencies and inadequate sample lengths, as quantified by cost increases and system reliability distortions. Methods to minimize distortions are introduced.

## 3 - Robust Optimal Control of Wind Farm with PHEVs Participating in Energy Market

Xiaojie Wang, University of Florida, Gainesville, FL, United States, Yongpei Guan

Previous studies suggest that plug-in hybrid electric vehicles (PHEVs), serving as electricity storage units, offer a perfect supplement to intermittent renewable energy. In this study, we manage a profit driven wind station with PHEVs as storage devices, where we can either sell the wind energy directly to the market or use it to charge the PHEV batteries and storage the electricity for future sales. We consider an innovative model and provide a robust solution considering price and renewable generation uncertainties. Our numerical results show the advantages of our proposed model.

## ■ TD50

North Bldg 231A

## Mixed-Integer Nonlinear Programming in Power Systems

Sponsored: Optimization/Integer and Discrete Optimization

Sponsored Session

Chair: Burak Kocuk, Sabanci University, Turkey

### 1 - Lazy Cut Generation for Semidefinite Programming

Hassan Lionel Hijazi, Los Alamos National Laboratory, P.O. Box 1663, MS B284, Los Alamos, NM, 87545, United States

In this talk, we will present the theory and the implementation of efficient cut generation algorithms that capture the strength of semidefinite programming relaxations and their application in ACOPE.

### 2 - The Value of Optimization Based Bound Tightening for Power Network Optimization

Carleton Coffrin, Los Alamos National Laboratory, Los Alamos National Laboratory, Los Alamos, NM, United States

Convexification is a fundamental technique in (mixed-integer) nonlinear optimization and many convex relaxations are parametrized by variable bounds, i.e., the tighter the bounds, the stronger the relaxations. This work investigates how optimization based bound tightening can improve convex relaxations for power network optimization. In particular, this work shows that the Quadratic Convex relaxation of AC power flow, enhanced by bound tightening, results in very small variable domains in the seminal Optimal Power Flow problem. Leveraging these improved bounds, experimental results demonstrate root-node optimality gaps that are less than one percent in the majority of test cases.

### 3 - Strengthening Optimal Power Flow Relaxations with Reference Bus Constraints and Bounds Tightening

Michael Lee Bynum, Sandia National Laboratories, Albuquerque, NM, 87123, United States, Anya Castillo, Jean-Paul Watson, Carl Laird

Math programming is a powerful tool frequently used to achieve reliable and efficient operation of the electric grid. We present recent advances toward including high fidelity, nonconvex transmission models in these optimization formulations. In particular, we show that existing relaxations of the alternating current optimal power flow (ACOPF) problem can be further tightened when we combine the McCormick relaxation with reference bus constraints and an appropriate bounds tightening procedure. With these strategies, we are able to reduce the optimality gap to less than 0.1% on all but 5 NESTA test cases with up to 300 buses by performing optimality based bounds tightening alone.

## ■ TD51

North Bldg 231B

## Scheduling

Contributed Session

Chair: William Ellegood, Sam Houston State University, Huntsville, TX, United States

### 1 - On Submodular Search and Machine Scheduling

Thomas Lidbetter, Assistant Professor, Rutgers Business School, 1 Washington Park, Newark, NJ, 07102, United States, Robbert Fokkink, László Vogh

We explore the connections between search theory and machine scheduling by studying an ordering problem proposed by Pisaruk (1992). A target is hidden in one of many locations, which must be searched in some order. The cost of searching an initial segment  $A$  of a given ordering is  $f(A)$  and the probability the target is hidden in  $A$  is  $g(A)$ , where  $f$  is a non-decreasing submodular function and  $g$  is a non-decreasing supermodular function. We want the ordering that finds the target in minimal expected cost. The problem is NP-hard and we present a new 2-approximation algorithm that generalizes well-known results in scheduling theory and establishes new ones. We also consider a game theoretic version of the problem.

### 2 - Simultaneous Scheduling of Machines and Vehicles with Alternative Machines in Flexible Manufacturing Systems

Dalila B. M. M. Fontes, INESC TEC, Rua Dr Roberto Frias, Porto, 4200-465, Portugal, Mahdi Homayouni

This work proposes a mathematical programming model for jointly scheduling production and transport in Flexible Manufacturing Systems considering alternative processing routes. Although production scheduling and transport scheduling have been vastly researched, most of the works address them independently. In addition, the few that consider their simultaneous scheduling assume job routes as an input, i.e., machine-job allocation is previously determined; however, in FMSs this is an important source of flexibility that should not be ignored. Results are reported for small-sized instances.

### 3 - Multi-period Lot-sizing with Supplier Selection: Complexity and Algorithms

Guohua Wan, Professor, Shanghai Jiao Tong University, 1954 Huashan Road, Antai College of Economics & Management, Shanghai, 200030, China, Meichun Lin, Woonghee Tim Huh

We consider a multi-period lot-sizing problem with multiple products and multiple suppliers. The objective is to determine the order quantities for each product from each supplier in each period to minimize the total cost over the planning horizon, including supplier-dependent fixed costs, variable purchase costs and product-dependent holding costs. We show the intractability of the problem in general and study three polynomial-time solvable cases of the problem. For these three cases, we analyze the structural properties, and propose dynamic program solution algorithms. We also develop a heuristic algorithm for the general case and computationally show that it works well.

### 4 - Utility Based Priority Scheduling Rules in Dynamic Job Shops with Customer Balking

William Ellegood, Sam Houston State University, Huntsville, TX, 77341, United States, Kevin D. Sweeney, Stanislaus Solomon, Mitch Millstein

This research examines a particular class of job shops where individual jobs have the option to forgo using the job shop (known as balking) due to expected poor levels of service as a result of system congestion. Using a dynamic job shop with heterogeneous jobs, we use the expected utility of a job to predict the balking behavior of potential job shop users. We further use the metric of expected utility to derive and test new priority dispatching rules for job shops that face the possibility of customer balking. These new rules are then compared to other priority scheduling rules based on processing time.

### 5 - Scheduling And Sequencing To A Two-stage Stochastic Service System With Multiple Servers

Yang Zhan, Shanghai Jiao Tong University, 1954 Huashan Road, Antai College of Economics and Management, Shanghai, 200030, China, Siqian Shen, Guohua Wan

In this paper, motivated by the application in the surgical suite, we consider the scheduling and sequencing problem in a two-stage stochastic service system with multiple servers on each stage. The processing times of jobs on both stages are stochastic and there is no buffer between stages. Our goal to optimize the usage of servers, the assignment of jobs-to-server and the sequence of jobs with the objective of minimizing the total of opening cost and overtime cost. We investigate a stochastic optimization framework and a decomposition algorithm to address the problem. Finally, we apply the model and algorithm to surgical scheduling.



## 6 - Improving Patient Flow Metrics at Outpatient Clinics through Effective Scheduling by Modeling Two Stage Mean Risk Stochastic Programming

Samira Fazel Anvaryazdi, Louisiana Tech University, Ruston, LA, United States, Saravanan Venkatachalam, Ratna Babu Chinnam

We discuss methods for improving patient flow metrics at outpatient clinics through effective appointment scheduling policies by applying risk-averse two-stage stochastic mixed-integer linear programming. We improve patient flow metrics: direct and indirect wait time, provider's overtime and idle time considering patient's no-show behavior, stochastic server, follow-up surgery appointments, and overbooking. The aim is to increase throughput per session while providing timely care, continuity of care, and overall patient satisfaction as well as equity of resource utilization.

## TD52

North Bldg 231C

### Flash Session II

General Session

Chair: INFORMS, 5521 Research Park Drive, Suite 200, Catonsville, MD, 21228, United States

## 1 - Developing a Model to Select the Best Multiple Sites to Install Wind Farms

Nazanin Naderi, Youngstown State University, Youngstown, OH, 32606, United States, Shabnam Rezapour

Renewable energy production has gained popularity worldwide due to the rapid depletion of fossil fuels and a global effort to reduce carbon emissions to mitigate climate change. Because of the formidable costs associated with wind energy development, the locations for new wind turbines need to be carefully selected to provide the greatest benefit for a given investment. This paper primarily focus on developing a model to find the best sites among alternative sites, could help find the efficient wind resources and lands that are well suited for wind turbines. The model developed in this paper compares combined sites based on nine different criteria and prioritizes them.

## 2 - Robust Service Network Design for Disaster Relief

Syed Tariq, Lahore University of Management Sciences (LUMS), Shah House, A-10, Block 2, Chapal Sun City, Lahore, 75280, Pakistan,, Muhammad Naiman Jalil

The service network design problem we discuss is concerned with facility location and prepositioning of relief goods in the preparedness stage and the reliability of network performance during response. We argue that the location of facilities determines the possible damage to facility capacities, access to vulnerable populations in their time of need, and timeliness of resupplying the facility in the response phase. In addition to facility and network related uncertainties, we evaluate the service network design in terms of both deprivation and logistics cost when some locations are more prone to disaster-related damage than others.

## 3 - Optimizing the Redundancy of IoT Networks

Mohammad Askar Saoud, Kuwait University, P.O. Box 54, Shamiya, 71661, Kuwait, Hamid Al-Hamadi

In this paper, we aim to maximize the lifetime of IoT networks using a redundancy management approach. As such networks are set up, paths must be determined for the IoT devices. While increasing the number of paths (which reflects redundancy level) increases reliability, energy consumption also increases. Thus, one needs to choose paths such that proper reliability level is maintained and simultaneously energy consumption is minimized. So, we propose an INLP model to represent the problem, and our objective is to maximize the Mean Time to Failure (MTTF).

## 4 - Parking Reservation Disturbances

Su Xiu Xu, Department Head, Jinan University, 206 Qianshan Road, Zhuhai, 519070, China

This paper considers an auction-based parking reservation problem where a platform is the auctioneer and drivers are bidders. The platform manages multiple homogenous parking spaces. A winner may leave earlier or occupy the parking space longer than the time he has reserved. The phenomena are called (ex post) demand disturbances, which can only occur after the last auction terminates. The platform may punish or compensate a driver who causes demand disturbance. We investigate three types of driver behaviors: gain/loss neutrality, loss aversion, and gain seeking, and examine the reference effects. We propose an effective multi-stage Vickrey-Clarke-Groves auction mechanism.

## 5 - Inventory-routing Problem with Pick-up and Deliveries: Formulation, Solving Approach, and Sustainability Perspectives

Claudio Sterle, University "Federico II" of Naples, Via Claudio 21, Naples, 80125, Italy, Grazia Speranza, Claudia Archetti, Maurizio Boccia, Sforza Antonio, Maria Elena Nenni

The Inventory Routing Problem (IRP) consists in the distribution of one or more products from a supplier to a set of customers over a discrete planning horizon. In this work we address the IRP with Pickups and deliveries where a single commodity has to be picked up from pickup customers and delivered to delivery customers. A fleet of vehicles is available, starting and ending their routes at the supplier's depot. The objective is to determine a distribution and collection plan minimizing routing and inventory costs. We propose a flow formulation and a branch-and-cut algorithm. Computational results on benchmark instances show that the algorithm outperforms state-of-the-art methods.

## 6 - Agent Scheduling for Call Center Operation

Ayush Patnaik, IIT Kharagpur, A-318, VS Hall, IIT Kharagpur, Kharagpur, 721302, India, Swapnil Waghmare, Samik Raychaudhuri

Agent scheduling, including scheduling breaks, is an important problem for call center operations. In this presentation, we present an optimization model that aims to provide us with the best possible schedule while satisfying numerous constraints such as operational hours, breaks, no transportation etc. It gives us the optimal allocation of agents in each shift so as to minimize agent under-allocation for the forecasted chats. We use the result of this model in a follow-up model, which allocates breaks of different types e.g., training breaks, lunch breaks etc, to individual agents.

## 7 - A Drift-variance Diffusion Control Model for New Venture Creation

Zhengli Wang, Stanford University, 655 Knight Management Way, 655, Stanford, CA, 94305, United States, Stefanos Zenios

We model new venture creation as a stochastic control process in which the value of the venture evolves as a diffusion process, and the drift and variance is controlled by the entrepreneur. The venture goes bankrupt when the diffusion process hits a lower boundary and is successful with a substantial monetary reward when the process hits an upper boundary. The entrepreneur incurs cost for the controls she selects and her objective is to maximize her total cumulative infinite horizon reward. We analyze the situation where the entrepreneur has two control options and we demonstrate that the optimal policy is at most a two-interval policy.

## 8 - Addressing Orientation-symmetry in the Time Window Assignment Vehicle Routing Problem

Kevin Dalmeijer, Erasmus University Rotterdam, P.O. Box 1738, Tilbergen Building H8, Rotterdam, 3000 DR, Netherlands, Guy Desaulniers

The Time Window Assignment Vehicle Routing Problem (TWA VRP) is the problem of assigning time windows for delivery before demand volume becomes known. For TWA VRP instances that are difficult to solve by current methods, we observe many similar solutions in which one or more routes have a different orientation, i.e., the clients are visited in the reverse order. We introduce a new branching method that eliminates this orientation-symmetry from the search tree, and we present enhancements to make this method efficient in practice. Through computational experiments, we show that our algorithm outperforms other solution methods, and we solve 29 previously unsolved benchmark instances to optimality.

## 9 - Patrolling Security Games with Mobile Adversaries and Entrance Nodes

Zhifan Xu, Rutgers University, 18M Reading Road, Edison, NJ, 08817, United States

Patrolling is an important operational decision when safeguarding a public area against adversarial attack. In this paper, we proposed an infinite horizon Stackelberg security game on a graph where the defender commits to a patrolling strategy first. The attacker decides his intruding route by solving a Markov decision process given patroller's movement probabilities and location in each turn. We also introduced the concept of detection probability for each nodes in the graph to model the difficulties of searching different area. To find the Stackelberg equilibrium, we proposed a bi-level programming model that can be solved using bilinear programming and global optimization techniques.

## 10 - Deep Learning Applications in Financial Services

Trevor Kennedy, Ally Financial, Philadelphia, PA, United States

Deep learning, newest incarnation of machine learning is just beginning to be applied in industry. We present a case study of several applications of deep neural networks in the financial services industry including best practices and limitations of this approach.

## ■ TD53

North Bldg 232A

**Mechanism Design**

Sponsored: Auction and Marketing Design

Sponsored Session

Chair: Brian Baisa, Amherst, MA, 01002, United States

**1 - Dominant Strategy Implementation without Quasilinearity**Brian Baisa, Amherst College, Converse Hall, Office 211,  
Amherst, MA, 01002, United States

I study dominant strategy implementation in a private value setting where agents have non-quasilinear preferences. I show that a mechanism is dominant strategy implementable if and only if the mechanism is ex post implementable in a particular endogenously determined interdependent value quasilinear setting. A corollary of this result is that there is no efficient and dominant strategy implementable mechanism for auction settings where bidders have multi-unit demands and multi-dimensional types.

**2 - Auctions versus Negotiations and Information Revelation**Justin Burkett, Wake Forest University, 1834 Wake Forest Road,  
Department of Economics, Winston-Salem, NC, 27106,  
United States, Kyle Woodward

We consider a seller deciding whether to implement an auction or engage in sequential negotiations with potential buyers. We show that sellers generally prefer auctions to negotiations. In equilibrium, as in reality, bidders in either mechanism use jump bids to signal strength to their competitors. The seller's preference is robust to different assumptions about bidder entry, as well as to the introduction of entry costs. Compared to prior work, we argue that the equilibrium of our model aligns better with observed behavior (e.g., bidders use jump bids in both auctions and negotiations) and gives a clearer and more robust justification for why a seller might prefer to run an auction.

**3 - Contingent Payment Mechanisms for Resource Utilization**Hongyao Ma, Harvard University, 33 Oxford Street, MD 242,  
Cambridge, MA, 02138, United States, Reshef Meir,  
David C. Parkes, James Zou

We consider a multi-period assignment problem, where agents are uncertain whether or not they will have positive value for the future use of a resource, and where it is in the interest of the planner that resources be used and not wasted. We introduce the contingent payment mechanisms (CP), and show that when instantiated for a max penalty equal to the societal value for use of the resource, the CP mechanism is welfare optimal under a set of axiomatic properties. A special case of the CP mechanism maximizes utilization—the probability that the resource is used. We extend the results to assign multiple resources, and present simulation results to demonstrate the effectiveness of the CP mechanisms.

**4 - Non-exploitable Protocols for Repeated Cake Cutting**Shai Vardi, Assistant Professor, Purdue University, 403 W. State  
Street, West Lafayette, IN, 47907, United States, Omer Tamuz,  
Juba Ziani

We introduce the notion of exploitability in cut-and-choose protocols for repeated cake cutting. If a cut-and-choose protocol is repeated, the cutter can possibly gain information about the chooser from her previous actions, and exploit this information for her own gain, at the expense of the chooser. We show that there exist non-exploitable protocols that use a small number of cuts per day. Among our results are a non-adaptive non-exploitable protocol that uses 3 cuts per day on 2-dimensional cakes, and a separation between adaptive and non-adaptive protocols for 1-dimensional cakes.

## ■ TD54

North Bldg 232B

**Incentive and Process Design with Behavioral Considerations**

Sponsored: Behavioral Operations Management

Sponsored Session

Chair: Xiaoyang Long, University of Wisconsin-Madison, Madison, WI,  
53706, United States**1 - Judgmental Selection of Forecasting Models**Enno Siemsen, University of Wisconsin-Madison, Wisconsin  
School of Business, 975 University Avenue, Madison, WI, 53706,  
United States, Fotios Petropoulos, Nikolaos Kourentzes,  
Konstantinos Nikolopoulos

In this paper, we explored how judgment can be used to improve the selection of a forecasting model. We compared the performance of judgmental model selection against a standard algorithm based on information criteria. We also examined the efficacy of a judgmental model-build approach, in which experts were asked to decide on the existence of the structural components (trend and

seasonality) of the time series instead of directly selecting a model from a choice set.

**2 - The Behavioral Promise and Pitfalls in Compensating Store Managers**Shan Li, City University of New York, Baruch College,  
55 Lexington Avenue, New York, NY, 10010, United States,  
Kay-Yut Chen, Ying Rong

We theoretically and behaviorally studied profit-sharing and target-with-bonus compensation schemes in an inventory management context. Our experimental data reveals behavioral promise and pitfalls of the two widely used incentive compensation schemes, and it further suggests systematic deviations from the theoretical benchmarks. Based on the experimental findings, we manipulate the behaviors and engineer the design of the compensation scheme through two additional treatments, to explore potential improvement of the mechanism. Our results have implications for the design of incentive schemes in practice.

**3 - How Supply Chain Risks Influence Supplier Selection and Ordering Decisions: A Behavioral Investigation**Vincent (Junhao) Yu, University of Minnesota, Minneapolis, MN,  
United States, Karen L. Donohue

Various types of risks occur in business supply chains. When choosing suppliers, buyers need to carefully evaluate the risk and cost profiles of the candidates in order to make appropriate ordering decisions. In this study, we combine modeling and experimental methods to investigate buyer ordering behavior when facing suppliers with different types and levels of risks. Potential risks include reliability-related issues that disrupt the flow of supply and responsibility-related issues that influence the flow of customer demand. Our findings provide insights for supply chain professionals looking to better understand the behavioral biases that enter into their sourcing decisions.

**4 - Wage Transparency in Sales Agents' Compensation Schemes**Xiaoyang Long, University of Wisconsin-Madison, Wisconsin  
School of Business, 975 University Avenue, Madison, WI, 53706,  
United States, Javad Nasiry

Sales agents with social preferences evaluate their pay in comparison with their peers' and experience a positive or negative utility. We characterize the optimal salesforce compensation schemes in this context and identify the conditions under which wage transparency benefits the firm.

## ■ TD55

North Bldg 232C

**Decentralized Innovation**

Emerging Topic: New Product Development

Emerging Topic Session

Chair: Sreekumar Bhaskaran, SMU

**1 - Strategic Investment in a Budget Constrained Firm's R&D**Junghee Lee, Assistant Professor, Tulane University,  
7 McAlister Dr, New Orleans, LA, 70118, United States

We model a bilateral monopolistic supply chain in which a supplier's sales are linked with a manufacturer's costly R&D. The manufacturer has a limited budget for R&D. The supplier can influence the manufacturer's R&D spending by setting the wholesale price and/or investing in R&D. We find that if the budget is common information, the manufacturer's profit can decrease in its budget, leading the manufacturer to hide the R&D budget. To overcome this information distortion, we develop a simple and implementable threshold policy based on mechanism design. The separating equilibrium can be obtained with fewer structural assumptions about the suppliers prior belief about the budget.

**2 - Outsourcing and Offshoring in Complex Product Development Projects**Jurgen Mihm, INSEAD, Boulevard de Constance, 77305, France,  
Ole Frauen, Arnd H. Huchzermeier

Large organizations that develop complex products are faced with the question of how to decompose and allocate product development work across geographic, or organizational boundaries. Distributing work may offer immense time and cost savings. However, finding a good allocation of work packages to development entities continues to be a challenge for many companies in practice. Based on an extensive data set involving all development projects of one of the largest car manufacturers worldwide, we provide insight into how to best offshore and outsource product development.

**3 - Firm Clockspeed: Toward a Theory of Relativity**Sina Moghadas Khorasani, Student, University of Utah,  
Salt Lake City, UT, United States, Glen M. Schmidt

Intel runs perceptively fast compared to Pfizer (its revenues stem from new products, product lifespans are short, and cost reduction is rapid), yet profit growth is no higher. In this paper, we explore how perceived clockspeed contributes to profit growth (we call this relative clockspeed) and economic progress (we call this absolute clockspeed).

#### 4 - Innovation Positioning Under Disruptive Threats

Xiaochen Gao, University of California-San Diego, La Jolla, CA, 92093, United States, Viswanathan Krishnan, Sreekumar R. Bhaskaran

Typically, while developing a new technology or product, a firm would also have a set of products which it currently makes available to consumers. As a result, one of the key decisions of a firm after developing a new product is its product positioning strategy. After having invested in and developed a new product, a firm has to decide whether this product should replace the existing line of products or whether both the new and old products be sold simultaneously to consumers. In this paper, we develop a framework for studying such an integrated product development and portfolio design problem. Specifically, we examine the value of retaining an existing lower quality product after developing a new higher quality version of the same product family. The economic and game-theoretic analysis used to model this problem brings forth several interesting insights. One of the key results of this research is that a product-line based approach to NPD can provide significant strategic advantages to a firm. In contrast to existing literature on development intensive products, we show that this strategy allows a firm to cover multiple market segments and price discriminate between consumers. Interestingly, the value of pursuing a product line based approach assumes greater significance under competition. Having multiple products in its product-portfolio enables a firm to extract higher margins from its high-end markets without forgoing its presence in low-end markets. Moreover, when the level of competition is high, cannibalization tensions in maintaining a larger portfolio could also serve to deter mutually destructive price competition.

#### ■ TD56

West Bldg 101A

#### Screening and Treatment Models

Sponsored: Health Applications

Sponsored Session

Chair: Steven Shechter, University of British Columbia, Vancouver, BC, V6T 1Z2, Canada

#### 1 - Screening for Breast Cancer: The Role of Supplemental Tests and Breast Density Information

Burhaneddin Sandikci, University of Chicago, Booth School of Business, 5807 South Woodlawn Avenue, Chicago, IL, 60637, United States, Mucabit Cevik, David Schacht

The imperfect nature of mammography led to increased consideration of supplemental ultrasound and Magnetic Resonance Imaging (MRI) screening for timely detection of breast cancer, particularly for high-risk women including those with dense breasts. Breast density not only impairs screening accuracy, but also significantly increases risk of developing breast cancer, resulting in disproportionate risk of death from breast cancer for millions of women with dense breasts. We formulate the optimal breast cancer screening problem using a partially observable Markov decision process model. We compare its results to mass screening guidelines and quantify the value of supplemental screening.

#### 2 - Partially Observable Collaborative Model for Optimizing Personalized Treatment Selection

Jue Gong, University of Washington, Seattle, WA, 98115, United States, Shan Liu

Personalized treatment selection has become an increasingly important topic in health care research. The main challenges include the modeling of individual disease progression dynamics and designing the adaptive treatment selection strategy. We developed the Partially Observable Collaborative Model (POCM), to learn the individual disease progression model under various treatment options when the true health state is hidden to the decision maker. Next, utilizing the learned individual models, a personalized treatment plan can be derived by solving a POMDP. This research helps to advance the development of artificial intelligent decision support tools for chronic disease care.

#### 3 - Analytics in Blood Pressure Management and Control: From Data to Decisions

Anthony Bonifante, Denison University, Granville, OH, 30106, United States, Turgay Ayer, Ben A. Haaland, Peter Wilson

Antihypertensive drug treatment can control elevated blood pressure and reduce the risk of cardiovascular disease. We propose data-driven models that combine stochastic optimization and statistics to identify the optimal thresholds for initiating treatment and for increasing the treatment dosage. We analytically characterize the expected value and variance of the hazard ratio, which enables us to easily compute the optimal treatment initiation and intensification decisions, and capture different attitudes towards risk (e.g. risk neutral or risk averse). Our findings have policy suggestions and may help guide future RCT design.

#### 4 - A High-fidelity Model to Predict Length-of-stay in the NICU

Kanix Wang, Research Professional, University of Chicago, Booth School of Business, Chicago, IL, United States, Walid Hussain, Arnab Sur, John R. Birge, Michael Schreiber, Daniel Adelman

Effective use of medical staff and clinical resources depends on the accuracy of length-of-stay forecasting to match required resources with patient load. Current forecasts are based on an initial severity ranking and are not updated as patients progress. This problem is particularly acute in the Neonatal Intensive Care Unit (NICU) setting because patient lengths of stay tend to be quite long and highly variable, extending from several days to many months. We develop a dynamic forecasting model, and apply machine learning, to predict remaining length-of-stay depending on a patient's severity scores history, clinical progression and demographic and environmental covariates.

#### ■ TD57

West Bldg 101B

#### Amy Cohn

Sponsored: Health Applications

Sponsored Session

Chair: Amy Cohn, University of Michigan, Ann Arbor, MI, 48109, United States

#### 1 - Simulating the Outcome of Make-ahead Drug Policies at an Outpatient Chemotherapy Infusion Center

Donald B. Richardson, University of Michigan, 2753 IOE Building, 1205 Beal, Ann Arbor, MI, 48109-2117, United States, Amy Cohn

We have developed a discrete-event simulation tool to evaluate a variety of policies for selecting which drugs to pre-mix for outpatient chemotherapy patients. By making patient-specific drugs ahead of appointment time, patient waiting time can be reduced but this comes at the risk of waste cost if the patient must defer treatment once arriving for their appointment and the drug must be discarded. We utilize data from the University of Michigan Rogel Cancer Center to validate our methods.

#### 2 - Evaluating Veteran Access to Eye Care Services Using Facility Location Models

Adam VanDeusen, University of Michigan, 1205 Beal Ave, Ann Arbor, MI, 48109, United States, April Maa, Amy Cohn

Many patients, including United States veterans, face barriers to accessing appropriate, affordable healthcare. These barriers can be addressed by optimizing clinic locations while delivering care that effectively utilizes providers' practice responsibilities. We present a model to evaluate veterans' eye care facility location options with consideration for overall system access. We further present a case study in which trained technicians perform visual disease screenings typically conducted by ophthalmologists. Our work may guide decision-makers in locating and staffing clinics to improve patient access.

#### 3 - A Comparative Analysis of Resident Block Scheduling Models

William Pozehl, Ann Arbor, MI, 48104, United States, Amy Cohn

Operations research approaches to block scheduling for medical residencies have emerged over the last several years. In particular, mathematical programming models have proven popular and generally successful. Still, though, computational complexity can make solving these models excessively time-consuming. We present a comparison of different modeling approaches and evaluate their performance in relation to a case study for an internal medicine residency program at a large academic hospital.

#### 4 - Stochastic Optimization Models for Childhood Vaccine Distribution Network: A Case Study in Niger

Zahra Azadi, Assistant Professor, University of Miami, Miami, FL, United States, Sandra D. Eksioglu

The main objective of this research is to increase vaccine coverage in low income countries by improving the performance of the corresponding supply chain. We propose a chance constraint programming model which identifies optimal supply chain designs and management strategies. The model considers the limited shelf life of vaccines, facility and transportation storage capacities, as well as variations in patient arrivals at health clinics. The proposed model is an extension of the supply chain network design model. A sample average approximation (SAA) method is used to solve the problem. We develop a case study for Niger by utilizing GeoNames Geographical Database and Demographic Health Survey.



## ■ TD58

West Bldg 101C

**Joint Session HAS/Practice Curated: Decision Analytics and Models for Medical Diagnostics**

Sponsored: Health Applications

Sponsored Session

Chair: Chun-An Chou, Northeastern University, Boston, MA, 02115, United States

**1 - SD-CNN: A Shallow-Deep CNN for Improved Breast Cancer Diagnosis**

Fei Gao, Arizona State University, 886 N. Cofco Center Court, Unit 1017, Phoenix, AZ, 85008, United States, Teresa Wu, Bhavika Patel, Yanzhe Xu

Deep learning has been widely implemented in practices for imaging based diagnosis. In this research, we first develop a shallow CNN to learn the mapping between low energy digital mammography (LE) and a more advanced breast imaging (recombined image) to tackle the less accessible issue of Contrast Enhanced Digital Mammography for broader clinical uses. A pre-trained deep CNN then takes both LE and "virtual recombined image" to generate novel features for improved breast cancer diagnosis. Experimental results indicate significant improvement from this proposed Shallow-Deep CNN approach.

**2 - Using Logical Analysis of Data as a Tool in Medical Decision Making**

Ruilin Ouyang, Northeastern University, Boston, MA, United States, Chun-An Chou

Transparent results (e.g., if symptom A and symptom B, then outcome C) in addition to achieving high accuracy are desirable as a priority goal in building decision tools for medical diagnosis or health care. In our study, we present a logical analysis approach to build a rule-based decision model for Unplanned ICU transfer. We formulate and solve a mixed-Integer programming model to generate effective logical rules with maximum margins iteratively, and in turn form a compact rule-based decision model. We also compare our computational results with other state-of-the-art supervised learning methods (logistic regression and decision tree).

**3 - Autism Risk Genes Prediction Using Spatiotemporal Gene Expression Data**

Ying Lin, University of Houston, Houston, TX, 77204, United States

Autism Spectrum Disorder is a constellation of neurodevelopmental presentations characterized by impairments in social and communication behavior. Finding causal autism genes is challenged by small effect of single gene and the lack of common risk loci. Although recent large exome sequencing studies of autism families have identified 65 autism risk genes, they represent only a fraction of the estimated genes involved in autism susceptibility. In this study, a gene ranking model is developed based on the identified genes and their brain specific spatiotemporal gene expression and applied to rank more than 25,000 unknown genes. The top ranked genes are potential to enrich the autism risk genes.

**4 - The Effect of Indeterminate Findings on the Cost-effectiveness of Lung Cancer Screening**

Iakovos Tournazis, Stanford University, Department of Radiology, James H. Clark Center, Room S255, Stanford, CA, 94305-5446, United States, Tsai B. Emily, Ayca Erdogan, Summer Han, Ann Leung, Sylvia Plevritis

The US Preventive Services Task Force recommends lung cancer (LC) screening for high risk individuals, yet the effect of indeterminate findings on the cost-effectiveness of LC screening is not established. We use a microsimulation model to estimate the cost-effectiveness of alternative LC screening strategies for the US general population under alternative levels of disutility associated with indeterminate findings. We find that as the effect of the disutility of indeterminate findings increases, the eligibility criteria for LC screening become more stringent and if large enough then biennial screening is cost-effective whereas, annual screening is cost-ineffective.

**5 - Improving Community Paramedicine via Data Science and Optimization: Selective, Proactive Management of ED Patients**

Andrew C. Trapp, Worcester Polytechnic Institute, School of Business, 100 Institute Rd., Worcester, MA, 01609, United States, Shima Azizi, Renata Konrad, Sharon A. Johnson, Brenton Faber

Community paramedicine is a recent healthcare innovation that empowers proactive visitation for chronically ill patients, often as follow-up visitations shortly after ED discharge. However, we are unaware of any studies that have considered it from the viewpoint of analytics. To that end, we purpose to reduce ED costs and increase patient welfare via our data-driven optimization approach. We use real hospital and community data to inform key decisions concerning provision of service, including vehicle and personnel scheduling and routing. We conclude by discussing computational findings.

## ■ TD59

West Bldg 102A

**Joint Session HAS/Practice Curated: OR Applications in Cancer Care**

Sponsored: Health Applications

Sponsored Session

Chair: Murat Kurt, Bristol-Myers Squibb, 3401 Princeton Pike, Lawrence Township, NJ, 08648, United States

Co-Chair: Iakovos Tournazis, Stanford University, Stanford, CA, 94305-5446, United States

**1 - A Generalized Latent Disease Detection Problem with Application to Active Surveillance of Prostate Cancers**

Zheng Zhang, University of Michigan, Ann Arbor, MI, United States, Brian T. Denton

We describe a generalized latent disease detection problem with patient-specific risk factors, a customized number of detection strategies for patients, and a general reward function. We formulate an integer programming model that considers patient-to-strategy assignment decisions and the test planning decision for each strategy. We develop a decomposition-based algorithm as a solution method for the model. We also provide insights based on the application of this model to optimize strategies for active surveillance of low-risk prostate cancers.

**2 - A Markov Decision Process Model to Define the Role of Active Surveillance for Small Renal Masses**

Jennifer Mason Lobo, University of Virginia, Charlottesville, VA, United States, Tracey L. Krupski

While the majority of small renal masses (SRMs) are indeed kidney cancer, a considerable proportion are either benign or demonstrate indolent behavior. Recent guidelines recommend active surveillance (AS) over definitive treatment for patients with limited life expectancy. In order to determine precisely which patients should be considered for AS, we developed a Markov decision process model to maximize life years or quality-adjusted life years for SRM patients over a ten year horizon, comparing AS, ablation, and surgical treatments. We present personalized treatment recommendations for patients based on demographics, comorbidities, and mass characteristics.

**3 - Evaluating the Effectiveness of Supplemental Breast Cancer Screening in Women with High Bi-rads Density**

Mahboubah Madadi, Louisiana Tech University, Ruston, LA, 712720029, United States, Sevda Molani

Since the enactment of the breast density notification law, there have been controversial debates over the necessity of this law. The law requires physicians to inform women with heterogeneously or extremely dense breasts of their breast density results, and the potential effect of high breast density on the sensitivity of mammography. In some states, the physicians are required to notify their patients of the possibility of using more sensitive supplemental screening tests. We develop a partially observable Markov model to evaluate the effectiveness of supplemental screening in term of the expected quality-adjusted life years (QALYs), number of false positives, and biopsies.

**4 - Personalized Lung Cancer Screening Strategies Using a Partially Observable Markov Decision Process**

Iakovos Tournazis, Stanford University, Department of Radiology, James H. Clark Center, Room S255, Stanford, CA, 94305-5446, United States, Oguzhan Alagoz, Ann Leung, Sylvia Plevritis

The US Preventive Services Task Force recommends lung cancer (LC) screening for high risk individuals aged 55-80 with at least 30 pack-years, and no more than 15 years since smoking cessation. Many other risk factors are associated with LC incidence, yet screening eligibility is solely based on age and smoking history, leading to sub-optimal screening strategies. We propose a partially observable Markov decision process (POMDP) that provides individualized optimal screening strategies for current and former smokers. Decisions are made based on the risk of the individuals accounting for previous screening results and changes in individuals' smoking behavior.

## ■ TD60

West Bldg 102B

### HAS Session #II

Sponsored: Health Applications

Sponsored Session

Chair: Bryan A. Norman, Texas Tech University, Lubbock, TX, 79409-3061, United States

#### 1 - Multi-appointment Patient Scheduling for Chemotherapy Scheduling

Maryam Keshtzari, Texas Tech University, Texas, Lubbock, TX, United States, Bryan A. Norman

Cancer clinics are often overwhelmed with a large number of patients requesting chemotherapy treatments. Many patients prefer to have their chemotherapy session on the same day they visit the oncologist. In this study a simulation-based optimization model is presented to create a more balanced schedule to improve patient wait time and reduce nurse workload stress. Different scenarios based on patient's acuity level and length of the infusion appointment are designed and evaluated considering uncertainties related to cancellations and no-shows.

#### 2 - Moving on Up: Appointment Rescheduling to Improve Outpatient Clinic Appointment Slot Utilization

Shannon Harris, The Ohio State University, 1262 Eastwood Ave, Columbus, OH, 43203, United States, Bjorn Berg, Jerrold H. May, Luis G. Vargas, Nathan C. Craig

It is a common assumption that outpatient clinics are passive participants in the appointment booking process. If a patient cancels an appointment during the lead time, and another patient does not book an appointment in the cancelled time slot, the slot will remain empty. However, if the clinic can actively manage the appointment bookings, it may be able to increase the expected utilization of its appointment slots by potentially rescheduling appointments during a scheduling horizon. We prescribe general rules for when and how such appointment movements should occur in order to maximize expected utilization.

#### 3 - Managing Interruptions in Appointment Schedules in Physician Clinics

Ali Dogru, University of Southern Mississippi, Hattiesburg, MS, 35406, United States, Sharif Melouk

Physician clinics often encounter interruptions that affect their operations and impact the patient experience. Thus, in this research, we develop an interruption management procedure employing real-time patient notification. We use stochastic optimization to determine optimal appointment intervals and simulation optimization to establish a notification policy. Experimentation provides managerial insights.

#### 4 - Outpatient Clinic Appointment Scheduling using a Multi-objective Table-input Simulation-optimization Approach

Mohammad Dehghanimohammadabadi, Northeastern University, 170 Brookline Avenue, Unit 1025, Boston, MA, 02115, United States, Mandana Rezaeiahari

Appointment scheduling (AS) is one of the key factors to enhance the patient satisfaction in healthcare services. A practical and robust appointment scheduling pattern allows clinics to utilize medical assets, equipment, and resources in an efficient manner. In this study, a multi-objective simulation-optimization (MSO) approach is applied to determine the most preferred appointment scheduling pattern for an outpatient clinic system with stochastic parameters. The developed MSO model is using the concept of table-experiment (appointments table) in a simulation environment (Simio) which is improved with an iterative metaheuristic algorithm (in MATLAB).

## ■ TD61

West Bldg 102C

### The Number of Undocumented Immigrants in the United States

Emerging Topic: INFORMS Special Sessions

Emerging Topic Session

Chair: Mohammad Fazel-Zarandi, Massachusetts Institute of Technology, MIT, Cambridge, MA, United States

#### 1 - The Number of Undocumented Immigrants in the United States

Mohammad Fazel-Zarandi, Massachusetts Institute of Technology, MIT, Cambridge, MA, United States, Jonathan S. Feinstein, Edward H. Kaplan

We apply standard operational principles of inflows and outflows to estimate the number of undocumented immigrants in the United States, using the best available data, including some that have only recently become available. We develop an estimate of the number of undocumented immigrants based on parameter values that tend to underestimate undocumented immigrant inflows

and overstate outflows; we also show the probability distribution for the number of undocumented immigrants based on simulating our model over parameter value ranges. Our conservative estimate is 16.7 million for 2016, nearly fifty percent higher than the most prominent current estimate of 11.3 million, which is based on survey data and thus different sources and methods. The mean estimate based on our simulation analysis is 22.1 million, essentially double the current widely accepted estimate.

## ■ TD62

West Bldg 103A

### Joint Session DM/Practice Curated: Data Science and Analytics for Business Decision-Making

Sponsored: Data Mining

Sponsored Session

Chair: Durai Sundaramoorthi, Washington University in Saint Louis, Saint Louis, MO, 63131, United States

#### 1 - Multistakeholder Recommendation with Provider Constraints

Edward Carl Malthouse, PhD, Northwestern, 1845 Sheridan Road, Evanston, IL, 60208, United States, Ozge Surur, Robin Burke

Recommender systems optimize the utility of the user, but often there are other stakeholders. One setting is multisided platforms, which match buyers and sellers and it is necessary to jointly optimize the value for both. We propose an integer programming model, where constraints reflect the goals of the different stakeholders. Our model is a post-processing step, so it can easily be added to an existing recsys to make it multistakeholder aware. For computational tractability, we reformulate the IP using the Lagrangian dual and subgradient optimization. We use two data sets to evaluate the utilities of buyers and sellers and show that our approximation can achieve good upper and lower bounds.

#### 2 - Frequently Bought Together: Market Basket Analysis with Shortened Web Link Click Data

Christopher M. Smith, Air Force Institute of Technology, 2795 Ridge View Ct, Xenia, OH, 45385, United States, James Gallagher

Social Media use has grown tremendously since the advent of "Web 2.0". To facilitate the sharing of information, link shortening has become a common method for fitting long web links into space-constrained social media posts. Additionally, most link shortening services provide analytic feedback to users such as how many clicks the link generated or a breakdown by location of those clicks. Market basket analysis using graph mining techniques was applied to this web link data to provide insight into an area's information dissemination patterns. Patterns of access, including by hardware platform and referral sources, within clusters of web domains provide feedback to market research analysts.

#### 3 - Pick-up, Delivery, or Both? An Online Grocer's Optimal Fulfillment Models

Chloe Kim Glaeser, Assistant Professor, UNC Kenan-Flagler Business School, 300 Kenan Center Drive, Chapel Hill, NC 27599, Chapel Hill, NC, United States, Xuanming Su, Ken Moon

We partner with an online grocery retailer to answer the practice-based question of the optimal mix of delivery zones and fulfillment models using data-driven analytics. We investigate (A) how consumers respond to the locally tailored fulfillment options made available to them by the online grocer, and (B) how to leverage data to customize locally available fulfillment options while scaling the retailer's operations. We employ a regression discontinuity design to find the effect of delivery introduction. Based on this empirical evidence, we build and estimate a structural model and perform a counter-factual analysis to estimate the revenue increase from additionally offering delivery.

#### 4 - Machine Learning Approaches to Modeling Category Sales: Implications for Optimal Store-Level Pricing and Promotions

Durai Sundaramoorthi, Washington University in Saint Louis, 10352 Conway Road, Saint Louis, MO, 63131, United States

We propose machine learning approaches - Regression Trees (RT), Bagging (Bag), Random Forests (RF), and Boosted Trees (BT) - with modified loss functions as candidate predictive models of product category profit as functions of marketing variables (price, display, feature, price promotion), both within and across categories at the same retail store. Using store-level weekly scanner data from 24 product categories in each of 9 stores of a supermarket chain over a period of 5 years, we estimate these machine learning models and compare their predictive performance on a validation set. We find that these models with modified loss functions are meaningful in the optimization context.

## ■ TD63

West Bldg 103B

**Joint Session DM/Practice Curated:  
Data Science for Engineering and Facilities Design**

Sponsored: Data Mining

Sponsored Session

Chair: Reza Alizadeh, University of Oklahoma, Norman, OK, United States

**1 - Parameter Design Optimization of Products with an Ordinal Categorical Response Using Random Forests**

Gulser Koksall, Professor, Middle East Technical University, Industrial Engineering Department, Ankara, 06800, Turkey, Secil Gulbudak Dil

We propose an alternative method for finding optimal settings of product and process design parameters for the case of an ordinal categorical product/process response. The method utilizes Random Forests for modelling mean and variance of the response at a given set of parameter settings. The method uses different weighting strategies of Random Forest, and it is applied on three case problems. Results obtained are compared with those of previous studies that used the same data sets.

**2 - Minimization of Cycle Time Variance in Smart Warehousing**

Mohamed El Tonbary, Georgia Institute of Technology, 755 Ferst Dr, Atlanta, GA, 30318, United States, Leon McGinnis

We are interested in the operational decision in central fill pharmacies of assigning drugs to dispensers to be collected by vials traveling on conveyors. More specifically, we are concerned with finding the drug assignment which minimizes the cycle time variance. We show that the organ pipe arrangement attains the minimum under the assumption of constant travel times between adjacent dispensers. In the case of varying travel times between dispensers, we propose a heuristic which performs well empirically, achieving an optimality gap in the order of 0.1%. Our results can be generalized to other applications as well.

**3 - Queueing Analysis of an MIAPP-AS/RS Order Picking Operation**

Jingming Liu, Research Assistant, University of Arkansas, Fayetteville, AR, 72701, United States, John A. White, Haitao Liao

An M/G/1 queue is used to analyze an MIAPP-AS/RS system, in which case-level order picking occurs at multiple in-the-aisle picking positions (MIAPP) located on the floor and mezzanine levels. The S/R machine is treated as a server, and picking positions are treated as customers. Picking positions generate demands for replenishment performed by the S/R machine. Performance measures are obtained analytically for dedicated and random storage policies, as well as for finite and infinite populations. The results yield insights into the impact of the storage policies on the performance measures and the conditions where an infinite population approximation is reasonable.

**4 - Using Multiple Surrogates for Metamodeling in Complex Engineering Systems**

Reza Alizadeh, Graduate Research Assistant, The University of Oklahoma, 202 W. Boyd Street, Room 219, Norman, OK, 73019-1022, United States, Liagye Jia, Guoxin Wang, Janet K. Allen, Farrokh Mistree

Surrogate models are commonly used to replace expensive simulations of engineering problems. Frequently, a single surrogate is chosen based on past experience. However, we may use all or a subset of the accurate surrogates. We aim at achieving the least accuracy loss using all or the combination of surrogates using multiple surrogates, cross-validation, covariance matrix approximation, and random forest methods.

## ■ TD64

West Bldg 104A

**Joint Session DM/Practice Curated: Data Science  
in Finance**

Sponsored: Data Mining

Sponsored Session

Chair: Ning Ning, University of Washington, Seattle, WA, United States

**1 - The Effect of Emotional Cues on Making Economic Decisions under Uncertainty**

Pieter Geelen, Maastricht University, Maastricht, Netherlands, Business Intelligence and Smart Service Institute, Heerlen, Netherlands, Stefano Bromuri, Stefano Bromuri, Mahdi Ebrahim, Mahdi Ebrahim, Deniz Iren, Deniz Iren

We investigate the understudied role of emotions on investors' decision. Specifically, we identify six basic human emotions (i.e. happiness, sadness, surprise, fear, anger, and disgust) expressed by S&P 500 CEOs during their earning conference calls and examine their effects on financial analysts' decisions

(i.e. retain, buy or sell shares). To identify CEOs' emotions in more than 500 calls we developed a deep learning algorithm trained by experts annotating vocal data in a subset of calls. Our findings shed light on underlying emotional mechanisms of financial decision-making under uncertainty, thereby contributing to behavioral economic theory.

**2 - Modeling Multivariate Time Series of Counts via Common Factors**

Fangfang Wang, University of Wisconsin, Madison, WI, United States

We develop a new parameter-driven model for multivariate time series of counts. The mean process is modeled as the product of modulating factors and unobserved stationary processes. The former characterizes the long-run movement in the data, while the latter is responsible for rapid fluctuations and other unknown or unavailable covariates. The latent processes are governed by possibly low-dimensional factors. This model is applied to analyze the intraday trading activity of U.S. stocks from ten sectors in the first quarter of 2012. Dynamic relationship between common factors adjusted by their associated loading and intraday volatility is also investigated.

**3 - In-sample Tangency Portfolio Based Portfolio Forecasting**

Kyungchan Park, PhD Candidate, The University of Iowa, 21 E. Market St, PBB S221, Iowa City, IA, 52242-1994, United States, Hongseon Kim, Seongmoon Kim

Representative portfolio selection model consists of two stages: 1) estimating input values, and 2) constructing portfolio by inputting the estimates. Though estimation errors on inputs are inevitable, optimizations construct portfolios sensitively to the fluctuation of inputs. To date, portfolio models have been designed to minimize the influence of estimation errors while maintaining the two-stage mechanism of optimization based on estimated. Portfolio forecasting method of this study was begun to find a method to utilize the most efficient in-sample portfolio outside of the two-stage mechanism by constructing portfolios using historical in-sample tangency portfolios as input values.

**4 - Multivariate Bayesian Structural Time Series Model**

Ning Ning, University of Washington, Seattle, Seattle, WA, United States

This paper deals with inference and prediction for multiple correlated time series, where one has also the choice of using a candidate pool of contemporaneous predictors for each target series. Starting with a structural model for the time series, Bayesian tools are used for model fitting, prediction, and feature selection, thus extending some recent work along these lines for the univariate case. We run an empirical study with one-step-ahead prediction on the max log return of a portfolio of stocks that involve four leading financial institutions. The extensive empirical study confirm that this multivariate model outperforms three other benchmark models.

## ■ TD65

West Bldg 104B

**Joint Session DM/Practice Curated:  
Data Science and Deep Learning III**

Sponsored: Data Mining

Sponsored Session

Chair: Muye Wang, Columbia Business School, 3022 Broadway, 4th Floor West, New York, NY, 10027, United States

**1 - Network Intrusion Detection Using Partially Labeled Cybersecurity Data**

Sandjai Bhulai, Vrije Universiteit Amsterdam, Faculty of Science, De Boelelaan 1081a, Amsterdam, 1081 HV, Netherlands, Jan Klein, Mark Hoogendoorn, Robert van der Mei, Raymond Hinfelaar

Network intrusion detection systems (NIDS) have been used to defend computer networks against malicious cyber activities. The lack of training data hinders discovery of new, previously unknown, intrusions. We use recent cybersecurity partially labeled data based on the 2017 Locked Shields exercise. We show how autoencoder and gradient boosting algorithms deal with missing labels on partially labeled data. The results were analyzed by a cybersecurity expert and confirmed that the models were able to classify the known intrusions as malicious and that they were also able to discover new intrusions. This shows how well an unlabeled dataset can be used to construct and evaluate a NIDS.



## 2 - A Comparison Between Different Machine Learning Algorithms for Better Accuracy in Trauma Outcomes Prediction

Fatima Almaghrabi, PhD Student, The University of Manchester, Booth street, Manchester, United Kingdom, Dong-Ling Xu, Jian-Bo Yang

Outcome prediction models are useful in identifying the extent of patient injuries and prioritising immediate life threats. This research aims to identify the most accurate tools for building a prediction model and to increase model accuracy to enhance the care services provided to trauma patients. Thus, the research attempts to identify which algorithms have the highest classification accuracy in predicting trauma outcome. The results of some machine learning (ML) algorithms, such as decision tree, logistic regression, random forest and neural network results were compared to the evidential reasoning rule.

## 3 - Flexible Job Shop Scheduling with Multi Agent Advantage Actor Critic

Jinkyoo Park, Korea Advanced Institute of Science and Technology, 291 Daehak-ro, Yuseong-gu, Daejeon, 34141, Korea, Republic of, Jaehyeong Chun, Jongwoo Ko, Jun Young Park

In this research, we propose a multi-agent reinforcement learning approach to schedule a semiconductor manufacturing process. A semiconductor manufacturing process is composed of a large number of sequential jobs conducted by different types of machines. The optimal scheduling policy seeks to minimize the makespan while satisfying various constraints. We formulate the scheduling problem as a multi-agent team game, and then derive the independent policy for each machine by using the multi-agent advantage actor-critic. Experiment results show that our decentralized multi-agent RL approach is effective compared to centralized scheduling approach or heuristic scheduling approach.

## 4 - Data Driven Sparse System Identification

Salar Fattahi, PhD, UC Berkeley, Berkeley, CA, 94702, United States, Somayeh Sojoudi

In this work, we study the system identification problem for sparse linear time-invariant systems. We propose a sparsity promoting estimator to identify the dynamics of the system with only a limited number of input-state data samples. Using contemporary results on high-dimensional statistics, we prove that logarithmic number of data samples is enough to reliably estimate the system dynamics. The developed estimator offers a small estimation error entry-wise and is capable of "exact recovery" of the underlying sparsity structure of the system with small number of data samples. We demonstrate the effectiveness of our approach through different case studies.

## 5 - Deep Learning in Finance - Estimation of Factor Models

Muye Wang, Columbia Business School, 3022 Broadway, Uris Hall, 4H, New York, NY, 10027, United States

Factor analysis is a statistical method used to describe variability among observed, correlated variables in terms of a potentially lower number of unobserved variables called factors. By using a variational autoencoder framework, we are able to incorporate outside relevant information to improve linear factor model's predictive performance. In addition, we also consider extending the traditional linear factor model to a non-linear framework. Finally, we conduct numerical experiments using SP500 daily return data and trading volume data to illustrate the superior performance.

## TD66

West Bldg 105A

### Joint Session DM/Practice Curated: Intriguing Tweaks in Data Science I

Sponsored: Data Mining

Sponsored Session

Chair: Özge Süer, Northwestern University, 1310 Chicago Avenue 3H, Evanston, IL, 60201, United States

## 1 - A New Fuzzy Set and Quadratic Surface SVM Approach for Misclassified Classification with Applications

Jian Luo, Associate Professor, Dongbei University of Finance and Economics, No. 217 Jianshan Street, Shahekou District, Dalian, 116025, China, Ye Tian, Zhibin Deng

To handle misclassified classification problem, this paper proposes a totally new method which first adopts the intuitionistic fuzzy set method to detect those misclassified points, then deletes their labels, and utilizes their full position information to build a semi-supervised kernel-free quadratic surface SVM model. Besides, a branch-and-bound algorithm is designed to improve the efficiency and accuracy. Some numerical tests on artificial and real datasets verify the superior performance of proposed method among several benchmark methods. Furthermore, the proposed method is applied to brain-computer interface and credit risk assessment, which strongly demonstrates its effectiveness.

## 2 - As Good as it Gets? Upper Bounds on Prediction Performance

David Anderson, Villanova University, Philadelphia, PA, United States, Margret V. Bjarnadottir

Taking only an assumption that "very similar" observations should have similar predictions to each other, we formulate a linear program to generate upper bounds on the possible predictive accuracy of a given outcome, using data contained in a dataset. We show results on multiple real-world and simulated datasets.

## 3 - Building Interpretable and Highly Accurate Supervised Learning Models

Abdelaziz Berrado, Mohammed V. University, BP 765, Avenue Ibn Sina, Agdal, Rabat, 10080, Morocco

Rule based classification algorithms such as CART are very attractive in several applications. They owe their popularity to the simplicity of the tree-building algorithm and the actionability of the resulting models. These algorithms suffer, however, from instability due to the tree building process: they perform greedy searches for rules, which could lead to missing important rules. Ensemble methods can mitigate this weakness of individual tree learners. They result, however, in blackbox models and are unable to provide insights into the structure of the predictive model. We discuss in this work ongoing research aimed at building accurate and highly actionable classification models.

## 4 - Data Analytics as a Tool for Problem Structuring

Patrick Hester, UNC Asheville, 28 Gibson Rd., Asheville, NC, 28804, United States

Data analytics is everywhere, from healthcare to business to higher education. Analysts use it to understand, predict, and improve an organization's performance, as a fundamental tool in one's Hard OR toolbox. This perspective misses out on an equally valid, yet overlooked, application of analytics to help us frame our problem; in this arena, data analytics can be very powerful. I will argue for the use of data analytics in the problem structuring (or Soft OR) phase, as a natural complement to its continued use during the solution phase of a problem engagement.

## 5 - Coefficient Tree Regression for Discovering Hidden Structure

Zge S rer, Northwestern University, 1310 Chicago Avenue 3H, Evanston, IL, 60201, United States, Daniel Apley, Edward C. Malthouse

The proliferation of technologies allows us to collect datasets of immense size with a large number of variables. In practice, many groups of predictors often share a common regression coefficient, but the groups are unknown. We propose an algorithm called coefficient tree regression to discover the unknown group structure by utilizing the properties of linear regression in an efficient way. We avoid matrix operations and speed up the computation to obtain an efficient algorithm. Our method achieves high accuracy competitive with existing methods. Finally, we test our algorithm with real datasets and demonstrate that it yields interpretable models by exploring the relations between predictors.

## TD67

West Bldg 105B

### Joint Session ISS/Practice Curated: Mobile App, Commerce, and Analytics

Sponsored: Information Systems

Sponsored Session

Chair: Zhan Shi, Arizona State University, Tempe, AZ, 85251, United States

## 1 - Are Gaming Apps and Social Media Apps Adversaries or Partners to Education Apps? An Empirical Analysis

Sangpil Han, Arizona State University, Tempe, AZ, United States., Sungho Park, Sanghak Lee, Wonseok Oh

This paper examines an empirical question of whether spending time on hedonic apps such as Facebook and Angry Birds promote or impede users' usage of educational apps. We investigate this question using an individual-level app usage time data set.

## 2 - Personalized Targeting to Tackle the Challenge of Low Engagement in Mobile Apps: Combining Structural Hidden Markov Model and Field Experiment

Yingjie Zhang, Carnegie Mellon University, Pittsburgh, PA, United States

Low engagement rates and high attrition rates have been formidable challenges for mobile apps and their long-term success, especially for those whose revenues derive mainly from in-app purchases. This paper proposes a new structural forward-looking Hidden Markov Model (FHMM) and combines it with a randomized field experiment on app notification promotions. Overall, the novel feature of our paper is to propose a new approach of personalized targeting to tackle the challenge of low engagement in mobile apps by combining structural model and field experiment.

### 3 - Human Behavior in Physical Space and Virtual Space

Lei Dong, MIT, Cambridge, MA, United States

With the widespread of smart phone and location-based services, human 'movements' in the physical space and virtual space are recorded simultaneously. As far as we know, many human mobility patterns in physical space have been studied before, while there are a lot of open questions not be reached combing two spaces together: Does the virtual world have similar patterns of movement with physical space? Are there any interplay patterns between online and offline behavior? How do demographic properties matter in these two spaces? With a mobile phone dataset documenting detailed online and offline behaviors, we are seeking a deep understanding of humans behaviors in online and offline spaces.

### TD68

West Bldg 105C

#### Joint Session QSR/Practice Curated: Spatio-Temporal Data Analysis and Applications I

Sponsored: Quality, Statistics and Reliability

Sponsored Session

Chair: Jian Liu, University of Arizona, Tucson, AZ, 85721, United States

Co-Chair: Shyam Ranganathan, Virginia Polytechnic Institute and State University, Blacksburg, VA, United States

Co-Chair: Xiao Liu, University of Arkansas, University of Arkansas, Fayetteville, AR, 5, United States

#### 1 - Spatial Variable Selection and an Application to Virginia Lyme Disease Emergence

Yili Hong, Virginia Polytechnic Institute, 213 Hutcheson Hall, Department of Statistics, Blacksburg, VA, 24061, United States

Lyme disease is an infectious disease that is caused by a bacterium called *Borrelia burgdorferi sensu stricto*. One of the research objectives for the infectious disease community is to identify environmental and economic variables that are associated with the emergence of Lyme disease. In this paper, we use a spatial Poisson regression model to link the spatial disease counts and environmental and economic variables, and develop a spatial variable selection procedure to effectively identify important factors by using an adaptive elastic net penalty. The proposed methods can automatically select important covariates, while adjusting for possible spatial correlations of disease counts.

#### 2 - Penalized Spatio-temporal Regression for Video Monitoring of Additive Manufacturing Process

Hao Yan, 699 S. Mill Ave, Tempe, AZ, 85281, United States

In this work, we focused on detecting the local occurrence of the "hot-spot event" in the metal additive manufacturing (AM) process. Here we propose to model the temporal behavior of the hot-spot event by the autoregressive model and propose a spatial-temporal decomposition approach to isolate the hot-spot event from the background. We also propose a control chart scheme to tell when the event actually happens. The proposed methodology is validated using both simulation and case study in metal AM.

#### 3 - Spatio-temporal Modeling of Topic Flows with an Information Diffusion Monitoring Application on Social Networks

Shyam Ranganathan, Virginia Polytechnic Institute and State University, VT, Blacksburg, VA, United States, Scotland Leman, Peter Hauck, James Hawdon

Spatio-temporal topic flow modeling can be used to understand how information diffusion takes place on networks. We present an extension of the popular Latent Dirichlet Allocation (LDA) model to include spatial and temporal diffusion using ideas from the Gaussian process (GP) and the timeseries literature. We show an application where such a model can be used to monitor how information diffuses on social networks such as Twitter. We build a 'polarization barometer' based on the spatio-temporal model and use it to evaluate the amount of polarization generated by the information diffusion.

#### 4 - A Generic Framework for Multisensor Degradation Modeling Based on Supervised Classification and Failure Surface

Changyue Song, University of Wisconsin, Rm 3221, Mechanical Engineering Building, 1513 University Ave, Madison, WI, 53715, United States

We propose a generic framework for multisensor degradation modeling. Specifically, we model each sensor signal based on random-effect models and characterize failure events by a multi-dimensional failure surface. To overcome the challenges in estimating the failure surface, we transform the degradation modeling problem into a supervised classification problem, where classifiers can be incorporated to estimate the degradation status of the unit based on the underlying signal paths, i.e., the collected sensor signals after removing the noises. The proposed framework is also capable for sensor selection, able to handle asynchronous sensor signals, and easy to implement in practice.

### TD69

West Bldg 106A

#### Reliability Data Modeling and Analysis

Sponsored: Quality, Statistics and Reliability

Sponsored Session

Chair: Kangwon Seo, University of Missouri, Columbia, MO, 65211, United States

#### 1 - Comparing Two Kaplan-meier Curves with the Probability of Agreement

Lu Lu, Assistant Professor, University of South Florida, 4202 E. Fowler Ave., Tampa, FL, 33544-8861, United States, Nathaniel Stevens

The probability of agreement has been used as an effective strategy for quantifying the similarity between the reliability of two populations by accounting for a practically important difference. This talk discusses two approaches for assessing the probability of agreement and its associated uncertainty for comparing the Kaplan-Meier curves for estimating the reliability of two populations. The first approach provides an easy assessment based on large sample approximations. The second approach offers more precise estimation by using the fractional random-weight bootstrap approach. The methods are illustrated with examples for comparing the reliability curves of related populations.

#### 2 - Nonparametric Bayesian Network Approach System Reliability Analysis

Rong Pan, Arizona State University, School of Computing Informatics & Decision Sys, P.O. Box 878809, Tempe, AZ, 85287-8809, United States, Dongjin Lee

In this talk we present the a nonparametric Bayesian network method for evaluating a complex system's reliability while considering the uncertainty in system reliability structure and in component reliability assessment.

#### 3 - Realtime Flight Anomaly Detection and Health Management

Ashwin Rai, Arizona State University, Tempe, AZ, United States

A statistical model for in-flight aircraft health management has been developed, with the capability of automated feature extraction, dimension reduction, and anomaly detection. To efficiently handle the high-dimensional flight data, information is de-noised, fused, and encoded following which a multivariate Gaussian mixture model is developed to train the flight data with limited amount of fault cases and form a global probability distribution of the aircraft performance. A robust cross-validation method is then implemented to obtain the optimal safety threshold of the aircraft performance. Results indicate that the developed model can detect faulty operations with short time-lags.

#### 4 - Time-to-failure Analysis of Hollow Shafts in High Speed Trains with Fatigue Crack

Ruochong Liu, Tsinghua University, Yanfu Li

Reliability of the hollow shaft, the critical component in high speed trains, has been a significant issue concerned by the researchers and administrators in the railway domain. Fatigue crack is one of the main failure modes in hollow shafts. Therefore, a stochastic model combining the physics-of-failure mechanism has been established to describe the randomness of fatigue crack growth, which is partially incurred by the uncertainty of the axle force during the operation of the train. A Monte Carlo method has been conducted to simulate the degradation path of crack growth and estimate the distribution of time-to-failure of hollow shafts.

#### 5 - A Hybrid Network Model for Information Fusion in National Airspace System

Yuhao Wang, Arizona State University, Tempe, AZ, United States, Yongming Liu, Yongming Liu

This paper present a hybrid network model combining the classical Bayesian method and the Maximum Entropy method called the Bayesian-Entropy Network (BEN). With the proposed method, the information fusion from various sources can be achieved. The BEN method can take in information other than point data/observation as constraints. It is demonstrated in Air Traffic Control (ATC) system to model human knowledge and empirical information to help the risk assessment and accident prediction in the National Airspace System.

## ■ TD70

West Bldg 106B

### Joint Session DEA/Practice Curated: Applications II

Emerging Topic: Productivity, Efficiency and Data Envelopment Analysis

Emerging Topic Session

Chair: Umit Saglam, East Tennessee State University, Department of Management and Marketing, P.O. Box 70625, Johnson City, TN, 37614, United States

#### 1 - A Dea-based Empirical Analysis for Dynamic Performance of China's Regional Coke Production Chain

Panpan Xia, University of Science and Technology of China, Hefei, China, Jie Wu, Xiang Ji

Coke plays a critical role in China's national economic activities in the past several decades. However, because of the twofold pressures from the sustainability-concerned public and the international steel market downturn, China's coke industry steps into a dilemma. To help the industry solve its current problems, an empirical analysis for dynamic performance of China's regional coke production chain is demonstrated. Through adopting the slacks-based measure (SBM) in Data Envelopment Analysis (DEA) and a famous dynamic network DEA framework, this paper simplifies the coke production chain into a three-stage process, and captures the interactions between intermediates inside each stage.

#### 2 - Axiomatic Modeling of Fixed Proportion Technologies

Xun Zhou, Doctoral candidate, Aalto University School of Business, Runeberginkatu 22-24, Helsinki, 00100, Finlandi, Timo Kuosmanen

Understanding substitution possibilities of inputs/outputs is critical for efficient resource allocation and firm strategy. There are several important examples of fixed proportion technologies where some inputs and/or outputs are not substitutable. However, there is widespread confusion about appropriate modeling of fixed proportion technologies in DEA. We point out and rectify some misconceptions in the published literature, and show how the fixed proportion technologies can be correctly incorporated into the axiomatic framework.

#### 3 - Technical Efficiency in the Chilean Higher Education System: A Comparison with Traditional Measurements of Efficiency

Gianfranco Cossani, Universidad Catolica del Norte, Avenida Angamos 0610, Antofagasta, 1270709, Chile, Hernan Caceres, Loreto Codoceo, Jorge Tabilo

Data Envelopment Analysis (DEA) has often been used to evaluate the efficiency of higher education institutions in many countries. In Chile, few studies using this technique are available. In this work, we propose a network and dynamic DEA model where each university has a structure with resources shared by teaching and research. For our study case, we examined data from 2013 to 2017 of the Chilean System, and we compared our findings with efficiency scores obtained with four different DEA methods, in addition to rankings commonly used by the government and media outlets.

#### 4 - A Two-stage Performance Assessment of Utility Scale Wind Farms in Texas

Umit Saglam, Assistant Professor, East Tennessee State University, Department of Management and Marketing, P.O. Box 70625, Johnson City, TN, 37614, United States

A two-stage Data Envelopment Analysis (DEA) models are applied to evaluate productive efficiencies of the 95 large utility-scale wind farms' electricity generation in Texas, by using pre-determined three input and two output variables. The slack analysis and projection data are obtained for inefficient wind farms to find out benchmarking input-output variables. The sensitivity analysis is provided for the robustness of the DEA models with different combinations of input and output variables of the original model. Tobit regression models are conducted to investigate the reasons for inefficiency.

#### 5 - An Approach for Autonomous Target Selection for an Agent Swarm

Barin N. Nag, Professor, Towson University, Department of E-Business & Tech Management, College of Business & Economics, Towson, MD, 21252, United States, Sungchul Hong, Xiaoyin Wang

Decision making in target selection for a swarm of drones in military use is a complex process that requires the simultaneous consideration of a number of parameters, some of which may not be known with certainty. An approach is presented here for autonomous targeting decisions. The method uses a combination of Bayesian estimation to overcome problems of uncertainty, and Analogical Reasoning to aggregate a large number of observations to achieve a high level of confidence.

## ■ TD71

West Bldg 106C

### Joint Session ICS/Practice Curated: Networks and Their Applications

Sponsored: Computing

Sponsored Session

Chair: Hamidreza Validi, Oklahoma State University, Stillwater, OK, 74075, United States

#### 1 - The Most Betweenness Central Clique Problem

Foad Mahdavi Pajouh, University of Massachusetts Boston, Boston, MA, 02125, United States, Maciej Rysz, Eduardo Pasillao

This talk addresses the most betweenness-central clique problem, which is to find a clique of maximum betweenness centrality in a connected network. Central cliques have applications in corporate, social, communication, power grid, and biological network analysis. Complexity results, bounds, and a combinatorial branch-and-bound algorithm for solving this problem are presented.

Computational performance of the proposed algorithm is compared with that of a mixed integer programming technique on a test-bed of randomly generated graphs and real-life networks.

#### 2 - Sparse Model Estimation and its Applications to the Insurance Industry

Jessica Wai Yin Leung, University of Sydney, Sydney, Australia, Dmytro Masypura

We study the problem of sparse model estimation in the context of binary classification. We formulate the problem by extending the discrete Dantzig selector to accommodate a hinge loss function. To increase the efficiency in solving the problem, we reformulate the problem as a mixed integer linear optimisation problem (MILP) and propose to add additional bounds and warm-start algorithm to obtain near optimal solutions. Preliminary results show that our method is capable of recovering all the true features with high predictive accuracy within a reasonable time frame when the sample size is less than the number of features.

#### 3 - Interdicting Interdependent Smuggling, Money, and Laundering Networks

Thomas Sharkey, Rensselaer Polytechnic Institute, CII 5015, RPI, 110 8th St, Troy, NY, 12180, United States, Yeming Shen

We consider the problem of disrupting a transnational criminal organization (TCO) operating interdependent smuggling, money, and money laundering networks. The TCO will smuggle contraband across an international border, generate revenue from illegal sales, and then need to send the money back across the border via the laundering network. We examine a bi-level program that seeks to allocate law enforcement resources as to optimally disrupt these interdependent networks. Effective reformulation techniques are discussed as well as examining the impact of disrupting laundering networks across multiple TCOs.

#### 4 - Novel Group Centrality Metrics for Studying Essentiality in Protein Protein Interaction Networks

Saeid Rasti, North Dakota State University, Fargo, ND, United States

We propose a set of novel group centrality metrics and show their performance in estimating protein importance in protein-protein interaction networks. These centrality metrics are extensions of well-known nodal centrality metrics, such as degree, betweenness, and closeness, for a set of nodes which is required to induce a specific pattern. The structures investigated here range from the stricter induced stars and cliques, to a looser definition of an induced representative structure. We then propose mixed integer programming formulations to solve the problem exactly. Finally, the performance of the proposed metrics in identifying essential proteins in a series of organisms is indicated.



## ■ TD72

West Bldg 211A

### Information Security Risk Management

Emerging Topic: Cyber Security

Emerging Topic Session

Chair: Jingguo Wang, University of Texas-Arlington, Arlington, TX, 76019, United States

#### 1 - To Pay or Not to Pay? A Ransomware Conundrum: A Experimental Study

Yan Lang, University of Texas at Arlington, 701 S. Nedderman Dr, Arlington, TX, 76019, United States, Kay-Yut Chen, Jingguo Wang

Ransomware has become one of the widespread form of malware used in cyber-attacks. We develop a game theoretic treatment of a ransomware scenario with an attacker and multiple defenders. We show, by the use of human subject experiments, that whether a defender is willing to pay ransom can be affected by the ability for the defenders to coordinate, and in terms of implications of how the defender should invest in lowering the risk of an attack.

#### 2 - Accuracy, Confidence, Calibration, and Resolution: A Comparison of Measures of Individuals' Phishing Email Detection Ability

Yuan Li, University of Illinois at Springfield, Springfield, IL, United State, Jingguo Wang, H. Raghav Rao

This study compares four alternative measures of individuals' phishing email detection ability, including accuracy, confidence, calibration, and resolution. These measures reflect different qualities of a person in detecting phishing emails. An online survey experiment was conducted to empirically test these measures and their different antecedents. The study offers new insights into a person's phishing email detection ability. Theoretical and practical implications are discussed.

#### 3 - Defense Strategies under Cyber-Secure Market Interactions in Power Systems

Yihe Zhuo, Lawrence Snyder, Rick S. Blum, Shalinee Kishore, Parv Venkitasubramaniam

We present a tri-level model for cybersecurity in a smart grid. Our model optimizes the defense strategy that an independent system operator (ISO) should take against possible cyber-attacks. An attacker best-responds to this defense strategy to disrupt the system, and then the ISO dispatches energy consumption decisions. Our tri-level model cannot be solved exactly for reasonable instances, so we propose two heuristics, one based on a greedy approach and one that uses an analogy to facility location problems. We test the approaches on benchmark IEEE instances.

#### 4 - Closer for Connection, Closer to Risks? The Impact of Joining IXPs on Cybersecurity Threats

Qihong Wang, Singapore Management University, Singapore, Singapore

The internet exchange point (IXP) is the physical infrastructure through which Internet service providers (ISPs) and content delivery networks (CDNs) exchange Internet traffic between their networks (autonomous systems). According to the latest data published by Packet Clearing House, as of May 2018, 410 IXPs are running across 224 cities in 106 countries with ISPs and CDNs from 9077 autonomous systems. The emergence of IXPs, motivated for faster and cheaper internet peering, has created new challenge and opportunity to secure the internet infrastructure. In particular, for ISPs and CDNs originated from countries with heterogeneity in cybersecurity commitment, would linking to the same IXP increase each member's cybersecurity risk due to free rider and weakest link? Alternatively, would joining IXP reduce each member's cybersecurity risk as a result of the intensified competition for internet peering? This study investigates this issue using a panel data integrating the internet infrastructure migration and malicious internet traffic at autonomous system level. Given the flattening internet infrastructure contributed by the distribution of hundreds of IXPs all over the world, its business and policy implications on cybersecurity are discussed.

## ■ TD73

West Bldg 211B

### JFIG Panel Discussion: A Survival Guide for Junior Faculty

Sponsored: Junior Faculty JFIG

Sponsored Session

Chair: Chrysafis Vogiatzis, North Carolina A&T State University, Greensboro, NC, 27411, United States

Co-Chair: Canan Gunes Corlu, Boston University, Boston, MA, 02215, United States

#### 1 - JFIG Panel Discussion: A Survival Guide for Junior Faculty

Canan Gunes Corlu, Boston University, 808 Commonwealth Avenue, Boston, MA, 02215, United States

Panelists from both business and engineering schools will share tips about surviving the first years of your career.

#### Panelists

Shane Henderson, Cornell University, School of ORIE 230 Rhodes Hall, Cornell University, Ithaca, NY, 14853, United States

George Vairaktarakis, Case Western Reserve University, Dept of OR and OM, 10900 Euclid Avenue, Cleveland, OH, 44106-7235, United States

Hong Wan, Purdue University, School of IE, 315 N. Grant Street, West Lafayette, IN, 47907, United States

Julie L. Swann, North Carolina State University, Atlanta, NC, 30332-0205, United States

## ■ TD74

West Bldg 212A

### Joint Session MCDM/Practice Curated: MCDM Methodology in Emerging Applications

Sponsored: Multiple Criteria Decision Making

Sponsored Session

Chair: Serpil Sayin, Koc University, Istanbul, 34450, Turkey

#### 1 - Optimal Planning of a Multimodal Mobility System with Rideshare

Xi Chen, University of Michigan - Dearborn, 2290 Engineering Complex, 4901 Evergreen Rd, Dearborn, MI, 48128, United States, Armagan Bayram, Meigui Yu, Xiao Yu

Public transit aims at providing affordable and energy efficient transportation service to residents on their daily commutes. However, the high setup and operating cost of public transit greatly limits its accessibility and utilization. On the other hand, rideshare services have more route flexibility but bear higher cost and energy consumption per trip served. In this paper, we investigate the value of combining these two transportation modes in satisfying customer travel demand and improving system performance. We formulate an integer program for the multimodal transportation planning problem. We also propose an efficient heuristic to solve this optimization problem.

#### 2 - A Filtering-enabled Interactive Algorithm to Find Preferred Solutions of the Decision Maker

Gulsah Karakaya, Middle East Technical University, Business Administration Dept, METU, Universiteler Mahallesi, Ankara, 06800, Turkey, Ceren Tuncer Sakar

In the presence of multiple conflicting objectives, it is not straightforward to find the best solution. We develop an interactive approach to converge to preferred solutions of the decision maker. Iteratively, we present the decision maker small sets of alternatives and obtain preference information. We apply filtering to the data set to obtain more useful information. We use a weighted La distance function as the preference function. Using rankings data of Times Higher Education, we make tests with universities evaluated with five criteria and demonstrate that our method performs well.

#### 3 - Multiple-criteria Decision Making and Smart Systems: A Literature Review

Tung Cu, Bloomsburg University of Pennsylvania, 932 Country Club Dr., Bloomsburg, PA, 17815, United States

Although MCDM is an old school among OR domains, new breakthrough developments in smart systems have extended research in MCDM to new areas that were not possible before. The aims of the study are twofold. This paper first conducts a rigorous review of literature in both theoretical and empirical issues that address smart systems and MCDM methods, decision support tools and platforms in different contexts such as business, healthcare, education, politics, security and privacy. It then focuses on reviewing typical characteristics of smart system users in making their decisions. Findings on behaviors of traditional and nontraditional decision makers are presented in the paper.

#### 4 - Multi-dimensional Sensitivity Analysis in Operations Research, and its Importance for Preventive Healthcare Services

M Gabriela Sava, Assistant Professor, Clemson University, College of Business, 145 Sirrine Hall, Clemson, SC, 29634, United States, Luis Vargas, Jerrold H. May

We propose a method for analyzing the n-dimensional sensitivity and stability of an n-criterion AHP/ANP model, so as to more fully assess the impact of perturbations, such as those that are caused by additional information, on preferred alternatives. We illustrate our methodology by applying it to a preventative healthcare choice problem.

## ■ TD75

West Bldg 212B

### Joint Session MAS/DAS

Joint Session

Chair: Gregory S. Parnell, University of Arkansas, Fayetteville, AR, 72701, United States

#### 1 - Improving Analysis of Alternatives

Gregory S. Parnell, University of Arkansas, 4207 Bell Engineering Center, Fayetteville, AR, 72701, United States, Edward A. Pohl, Simon Goerger

The DoD is required to perform an Analysis of Alternatives (AoAs) to support major program milestone decisions early in the system life cycle. This paper reviews the statutory, defense department, and service guidance for AoAs. One of the major results of the AoA is a trade-off analysis that informs senior decision makers about the technical, cost, schedule risks of the potential new program. We report on a book project to document best practices for trade-off analyses and our research in the Engineering Resilient Systems program to improve the effectiveness and efficiency of AoAs.

#### 2 - Sensor Modeling for Military Applications

Randy K. Buchanan, USACE - ERDC, 3909 Halls Ferry Road, Vicksburg, MS, 39180, United States

Sensor models capabilities within the DoD were investigated for supporting tradespace exploration and analysis of unmanned aerial systems (UAS) integrated sensor systems and sensor payloads. The research was conducted to support examining the performance trades of various modalities including size, weight, and power to a rotary-wing and fixed wing aircraft. Sensor modeling and simulation supports the development and verification of optimized sensor systems and is required when knowledge of sensor system tradeoffs are deemed necessary, or the development of cutting-edge deployed systems are required.

#### 3 - Integrating the Cost Model with Set-Based Design

Randy K. Buchanan, USACE - ERDC, 3909 Halls Ferry Road, Vicksburg, MS, 39180, United States

Integrating cost models with set-based design concepts improves decision making capabilities for analysis of alternatives when implementing model-based engineering early in the design process. These principals were applied to a conceptual Army ground vehicle while integrating an engineering model with a cost model. Stakeholder requirements were used to incorporate value into the design tradespace and sensitivity analysis was applied to input parameters to determine effect on cost. The process of integrating SBD into the cost, engineering, and value models generated analytical insights of the design alternatives within the tradespace that provide guidance for future integration efforts.

#### 4 - Improving Personnel Selection through Multi Objective Decision Analysis

Christopher Smith, PhD, Air Force Institute of Technology, OH, United States, Joshua Deehr

Personnel selection has always and will continue to be a challenging task for the military special operations. They want to select the best out of a number of qualified applicants. What makes a successful candidate and how to compare candidates against each other are some of the difficulties that top tier organizations like the special operations face. Value Focused Thinking places criteria in a hierarchal structure and quantifies the values with criteria measurements, known as a decision model. The selection process can be similar to a college selecting their students. This research used college student entry data and strategic goals as a proxy for special operations applicants and standards.

## ■ TD76

West Bldg 212C

### Joint Session MIF/HAS: Models and Methods for Improving Patient Outcomes

Sponsored: Minority Issues

Sponsored Session

Chair: Gabriel Zayas-Caban, Madison, WI, 53706-1691, United States

#### 1 - Optimal Biomarker Testing and Subject Classification Under Limited Information

Seyedehsaloumeh Sadeghzadeh, Virginia Institute of Technology, Blacksburg, VA, 24060, United States, Douglas R. Bish, Ebru Korular Bish

Bio-marker testing is essential in public health screening. For many diseases, related bio-markers may have a wide range of concentrations among subjects, particularly among the disease-positive subjects. Furthermore, bio-marker levels may fluctuate based on external and subject-specific factors. These sources of variability can increase the chance of subject misclassification based on a bio-marker test. We study the minimization of the misclassification cost considering

regret and expectation-based objectives, and derive various key structural properties of their optimal solutions. Our case study establishes the benefits of the proposed models over current policies.

#### 2 - Precise: Pancreatic Cancer Prioritization and Screening Evaluation Tool

Lena Abu-El-Haija, NC, United States, Julie Simmons Ivy, Osman Ozaltin, Walter G. Park

Pancreatic cancer (PC) is the fourth cause of cancer death in the US and is projected to be second by 2030. Incidence of PC is low, but the mortality risk is high with 8% five-year survival. Early stage PC can be asymptomatic leading to late diagnosis after it may have metastasized. The key to improving survival is screening. SEER and secondary data were used to develop a model-based framework for evaluating screening policies. The model provides quantitative clarity to identify areas for future data collection to understand the behavior of PC and whom it targets. The model enables the development of personalized screening policies to include race, sex, and age that influence incidence and progression.

#### 3 - Improving Access of Low Back Pain Patients Through Prioritization at a Neurosurgery Clinic

Esma S. Gel, Associate Professor, Arizona State University, 699 S. Mill Ave., Tempe, AZ, 85287-8809, United States, Derya Kilinc

Low back pain (LBP) is often cited to cause significant health impairments for a large fraction of the population. Studies point to the high variability in treatment approaches and frequent mismatch between patient needs and services offered by providers from different specialties. This mismatch results in critical access problems for patients that truly need critical interventions such as surgery within a reasonable timeframe. We present findings from a number of ongoing projects to improve access of LBP patients at a neurological surgery clinic. Our analysis points to the importance of prioritizing surgical patients and demonstrates the potential improvements in patient access.

#### 4 - A Latent-Variable Approach to Potential Outcomes for Emergency Department Admission Decisions

Gabriel Zayas-Caban, University of Wisconsin, Mechanical Engineering Building, 1513 University Avenue, Madison, WI, 53706-1691, United States, Amy Cochran, Paul Rathouz, Keith Kocher

In emergency departments, providers weigh admissions against continued monitoring and treatment often without knowing their health state. We describe a framework to estimate the causal effect of admission decisions on patient outcomes from observational data. Admission decisions are modeled as a decision-making process in which the patient's health needs is a latent variable. We estimate latent health needs with limited knowledge of the decision process using the potential outcomes framework and assuming potential outcomes are independent from admission decisions within a latent health state. We apply our approach to patient encounters with the University of Michigan Health System.

#### 5 - A Data-driven Partially Observable Markov Decision Process for Optimizing Individualized Surveillance Strategies for Prostate Cancer

Weiyu Li, IOE department, University of Michigan, Ann Arbor, MI, United States, Brian T. Denton

Active surveillance (AS) is a strategy that involves regular clinical examinations, biomarker tests, and biopsies to monitor patients diagnosed with low-risk prostate cancer. The ideal strategy must strike a balance between the burden of testing and the benefit of early detection of progression to high-risk prostate cancer. We propose a hidden Markov model (HMM) to estimate the progression rate of cancer, and the sensitivity and specificity of the biomarker tests using longitudinal data from a large surveillance study. We use the HMM as the basis for a partially observable Markov decision process (POMDP) and present results for optimal strategies.

## ■ TD77

West Bldg 213A

### Health and Humanitarian Supply Chain Management

Sponsored: Public Sector OR

Sponsored Session

Chair: Pinar Keskinocak, Georgia Institute of Technology, Atlanta, GA, 30332, United States

Co-Chair: Seyma Guven-Kocak, Georgia Institute of Technology, Atlanta, GA, 30340, United States

Co-Chair: Pelin Pekgun, University of South Carolina, Columbia, SC, 29205, United States

#### 1 - The Roadside Healthcare Facility Location Problem

Harwin de Vries, INSEAD, Boulevard de Constance, Fontainebleau, 77210, France, Albert P. M. Wagelmans, Joris Van de Klundert

African truck drivers carry a high burden of HIV and are believed to significantly fuel its spread. We consider the problem to select locations for roadside healthcare facilities, so as to maximize their impact in terms of patient volume and continuity of access. We describe how we relate decisions to objectives and discuss how our model and its implementation in a decision support tool enable better location decisions.

## 2 - A Decision Support Tool for Strategic National Stockpile Inventory Policies

Erica L. Gralla, George Washington University, Washington, DC, 20052, United States, Kiren Ajrawat, Alyson Fintzy, Jillian Miles, Chris Shaffer

A decision support tool was developed to assist the Division of Strategic National Stockpile (DSNS) at the Centers for Disease Control and Prevention (CDC). The SNS is the nation's largest inventory of medical supplies to utilize during a disaster. In the case of a large scale public health emergency, there is a need to both serve emergency demand and to minimize the time to recovery and degree of degradation for the commercial supply chain. The simple decision support tool shows how different policies, such as SNS inventory levels and commercial production capacities, affect the response.

## 3 - A Framework for Re-designing Access-to-medicine Supply Chains

Nico Vandaele, KU Leuven, Naamsestraat 69, 0419.052.173, Leuven, 3000, Belgium, Catherine Jenny Decouttere, Stef Lemmens, Kim De Boeck, Mauro Bernuzzi, Stany Banzimana, Sherif Hassane

We present a five-step approach to (re-)design a supply chain. It encompasses stakeholder analysis and system definition, key performance indicator derivation, detailed modelling, scenario generation and ranking up to final scenario choice and implementation. We apply this to the (re-)design of a vaccine supply chain in humanitarian setting where development and disaster relief are connected. We provide examples and insights from the Sub-Saharan region.

## 4 - The Role of Food Banks in Determining the Effectiveness of the Snap Program

Luv Sharma, University of South Carolina, Columbia, SC, 29206, United States, Pelin Pekgun, Sanjay L. Ahire

The Supplemental Nutrition Assistance Program (SNAP) is the largest domestic hunger program in the United States, providing assistance to 47 million individuals. In this study we look at the role of food banks in increasing the reach of the SNAP program. Specifically we look at the interactions between resources dedicated to the SNAP program and characteristics of the food bank service area in influencing SNAP reach.

## 5 - Modeling for the Equitable and Effective Distribution of Food Donations Under Stochastic Capacities

Irem Sengul Orgut, Lenovo, 8209 Pritchett Farm Lane, Raleigh, NC, 27606, United States, Julie Simmons Ivy, Reha Uzsoy

Food insecurity is an increasing threat to people's health status and quality of life. In partnership with the Food Bank of Central and Eastern North Carolina, which distributes donated food to a 34-county service area, our objective is to achieve equitable and effective food distribution among the population at risk for hunger. Counties' capacities are the main source of uncertainty in this system as they constrain the total food distribution due to the need to distribute food equitably. We develop stochastic models for optimal food distribution and prove structural results. We illustrate our results and perform an extensive numerical study using historical data from our collaborating food bank.

## ■ TD78

West Bldg 213B

## Joint session SOLA/TSL: Alternative-Fuel Location Decisions with Service Constraints

Sponsored: Location Analysis

Sponsored Session

Chair: Ismail Capar, Texas A&M University, College Station, TX, 77843-3367, United States

Co-Chair: Yudai Honma, The University of Tokyo, Tokyo, 153-8505, Japan

## 1 - Designing an Electric Vehicle Charging Infrastructure under Customer Service Constraints

Ismail Capar, Texas A&M University, Industrial Distribution Program, Tamu 3367, College Station, TX, 77843-3367, United States, Ozgur M. Araz, Ibrahim Capar

While there is an interest in applying the flow-refueling location model (FRLM) to capacitated refueling stations including electric vehicle charging stations, the existing research primarily focuses on capacity as the only additional constraint for the FRLM. In this research, we introduce another aspect of the capacity decisions, namely drivers' perspective of minimizing mean sojourn time into FRLM and show results from extensive numerical experiments.

## 2 - Investigating the Alternative Fuel Vehicle Drivers' Deviation Tolerances for Refueling at Stations Off Their Paths

Okan Arslan, HEC Montreal, 5308 Ave Decelles, Montreal, QC, H3T1V8, Canada, Oya Ekin Karasan, Ali R. Mahjoub, Hande Yaman

Due to the limited range of alternative fuel vehicles (AFV) and the sparsity of the available alternative refueling stations, the AFV drivers cooperatively deviate from their paths to refuel. The deviation is generally bounded by the drivers' tolerance. Taking this behavior into account, we develop a natural model for the 'refueling station location problem with routing' based on the notion of length-bounded cuts. We quantify the impacts of the deviation tolerance of the drivers and the range of vehicles on the AFV use. We present insights on deviation characteristics of drivers and discuss the policy implications of our findings.

## 3 - New Node-based and Path-based Location Models for Urban Alternative-fuel Stations: Comparing Their Convenience and Coverage Abilities

Yudai Honma, The University of Tokyo, Ce405, Komaba 4-6-1, Meguro-ku, Tokyo, 153-8505, Japan, Michael J. Kuby

Researchers have proposed many different models for optimizing the locations of alternative-fuel stations to serve new vehicle adopters conveniently. This paper aims to compare the path-based vs. node-based modeling choice as fairly as possible from the perspective of minimizing total additional travel time and feasibly covering all demands with the same number of stations. For this comparison, we introduce two new station location models that extend the Flow Capturing Location Model (FCLM) and the p-Median Problem (PMP) by including consistently defined upper limits on vehicle driving range and degree of inconvenience on refueling trips.

## 4 - Locating Alternative-fuel Stations for Maximizing AADT Coverage and Ensuring Sufficient Spacing: A Case Study of CNG Truck Fueling

Qing Zhong, The University of Arizona, Tucson, AZ, United States, Daoqin Tong, Michael J. Kuby, Fangwu Wei, John W. Fowler, Keiron Bailey

This paper introduces two new arc-based coverage models for locating alternative fuel stations. The new models use arc traffic volumes in the form of AADT data to represent the demand. We incorporate a service area radius and a fractional correction factor to discount for the need to detour to the station and to avoid double-counting of AADT. Station spacing parameters allow the user flexibility in not locating new stations too close to each other or to existing stations. Redundant coverage due to the proximity of multiple stations is also addressed. We apply the models to planning a network of CNG fueling stations for heavy-duty CNG-powered trucking in the Southwest United States.

## ■ TD79

Hyatt, Curtis A

## Supply Chain Management IV

Contributed Session

Chair: Weimar Ardila, University of South Florida, 4207 Winding Moss Trail, # 208, Tampa, FL, 33613, United States

## 1 - Optimal Inventory and Price Competition in a Dual-Omnichannel Market

Bai Yang, PhD Student, Ajou University, San 5 Woncheon-dong, Yeongtong-gu, Suwon, 443 749, Korea, Republic of, Byeong-Yun Chang

With the fast development of science and technology, many retailers nowadays are increasingly adopting an omnichannel SCM to sell their products. In this paper, we model the competitive dual-omnichannel supply chains and the optimal inventory and price decisions are obtained.

## 2 - Coordinating Efforts for New Product Development: A Bilevel Programming Approach

Ece Zeliha Demirci, Postdoc Researcher, Eindhoven University of Technology, P. O. Box 513 5600 MB, Eindhoven, 5600MB, Netherlands, Nesim K. Erkip

Integration of marketing and sales functions with research and development are seen as key success factors for new product development. Our study deals with a problem faced by a manufacturer produces and/or distributes a new product to the market. The aim of the manufacturer is to increase the sales of the product while influencing the retailer to stay in the market. We model this setting as bilevel programming and provide characterization of the optimal solution.



### 3 - Writing to Bridge the Divide: Does Article Readability Affect Cross-citations in Operations and Supply Chain Management?

Seth Washispack, Arizona State University, Tempe, AZ, 85281,  
United States, Seongkyoon Jeong

There is a well-known divide between analytical and empirical researchers in the Operations and Supply Chain Management (OSCM) discipline. Although increasing the dissemination of knowledge across the two methodological camps can advance the development of the field, few solutions to this dichotomy have been suggested. Using 9,405 articles collected from the top four analytical and top four empirical OSCM journals, we tested how readability affects forward citations. Our results suggest that lowering the cognitive barrier in academic writing has the potential to advance the discipline within and between the analytical and empirical camps.

### 4 - Application of Statistical Learning in Demand Forecasting and Supply Chain Resilience

Weimar Ardila, University of South Florida, 4207 Winding Moss  
Trail, # 208, Tampa, FL, 33613, United States, Daniel Romero,  
Alex Savachkin

The inventory redundancy is basically a supply chain resilience strategy that allows a system to increase the safety stock levels to respond in the best way to sudden increases in demand. However, increases in the whole system's inventory levels also imply increases in costs related to the inventory management. A better forecast of the demand, from a statistical learning approach, could generate a better performance in the inventory policy, which would allow the system to react adequately to demand disruptions, without unnecessary increases in inventory levels.

## ■ TD80

Hyatt, Curtis B

### Practice- Supply Chain Management III

Contributed Session

Chair: Rajiv Saxena, APL Logistics, 11458 N. 128th Place, Scottsdale, AZ, 85259-3528, United States

#### 1 - Exploring the Role of Supplier and Product Characteristics in Vendor-managed Inventory

Roelof Post, University of Groningen, Akkerstraat 77, Groningen, 9717KG, Netherlands, Paul Buijs, Jaap Wieringa, Hans Wortmann

Research shows that transferring stocking decisions and ownership of inventories to suppliers can improve the performance of supply chains, but for which suppliers does this hold? Using both transaction data and empirical observations, we show how supplier and product characteristics affect the gains of a vendor managed inventory (VMI) implementation.

#### 2 - Random Capacity Disruptions in a Make-to-Stock Company with Stochastic Demand and Capacity

Antonio Arreola-Risa, Associate Professor, Texas A&M University, Mays Business School, INFO Department, 4217 TAMU, College Station, TX, 77843-4217, United States, Philip J. Mizzi, Barry Keys

A single-product, make-to-stock firm is considered. Demand and capacity are stochastic, with capacity experiencing random disruptions. Inventory is managed using a base-stock policy and demand stock-outs are back-ordered. The base-stock minimizing the economic cost of inventory holding and demand back-ordering is determined, as is the disruptions' impact on the optimal base-stock and cost.

#### 3 - Supply Chain Optimization in Action – Experiences of a Practitioner

Rajiv Saxena, Vice President, Supply Chain Solutions, APL Logistics, 11458 N. 128th Place, Scottsdale, AZ, 85259-3528, United States

An efficient and effective supply chain could be a competitive differentiator for a company. There is a major potential to cut logistics costs in the supply chain of a company through application of data analytics and optimization techniques. This presentation will include real-life data analytics and optimization case studies covering areas of network design, transportation optimization and facilities design and showcase how a 3PL provider can help a company significantly improve the efficiency and effectiveness of its supply chain.

## ■ TD81

Hyatt, Phoenix East

### Optimization IV

Contributed Session

Chair: Mehmet Unal, CoreLogic, 40 Pacifica, Suite 900, San Francisco, CA, 92618, United States

#### 1 - Cooperation Online and Brick and Mortar Retailers Returns and Induced Customer Traffic Implication

Maryam Mahdikhani, PhD Candidate, Rutgers University, 1 Washington Park, Room 442, Newark & New Brunswick, NJ, 07102, United States, Tolga Aydinliyim, Monire Jalili

Motivated by partnerships between online and Brick&Mortar (B&M) retailers where the online retailer operates a micro store within the B&M store (e.g., Amazon within Kohl's), we study consumers' returns channel choice and induced B&M store customer traffic implications as well as when such partnerships are profitable for the involved parties.

#### 2 - Scheduling Energy Consumption for Residential Stand-alone PV Systems

Dongjin Cho, Auburn University, 1324 Tulip Court, Auburn, AL, 36830, United States

Among various renewable energy sources, solar energy is considered an effective solution to the shortage of energy in the future. A stand-alone photovoltaic (PV) system is particularly significant in an isolated area where access to the grid is limited. Because solar energy generation primarily depends on the availability of solar irradiance, energy management becomes crucial while satisfying user comfort and system efficiency. In this paper, we propose an energy consumption scheduling model for a residential house with a stand-alone PV system and a battery. We develop a mixed-integer optimization model that uses consumption patterns and appliance priority to schedule the use of the appliances.

#### 3 - Optimizing Total Earliness and Tardiness Costs with Maximum Allowable Tardiness Limit Through Unrelated Parallel Machine Scheduling in Job Shops

Parsa Kianpour, Graduate Research Assistant, Wichita State University, Wichita, KS, 67206, United States, Deepak Gupta, Krishna krishnan, Bhaskaran Gopalakrishnan

Motivated by the practical scheduling problem of job shops, this study evaluates unrelated parallel machine scheduling models and proposes a new model considering effects of maximum allowable tardiness. It compares the total cost provided by the proposed model with the case in which there is no limitation on tardiness. In addition, the existing model in the literature is simplified to reduce computational time and enable corporate scheduling staff to use the model efficiently. The model is validated using data collected from a local job shop that manufactures aerospace parts.

#### 4 - Optimization of Solid Waste Management in a Metropolitan City: A Case Study in Chennai, a Major Metropolitan City in India

Sumit Saxena, IIT Madras, Chennai, India, Chandrasekharan Rajendran

The aim of this research is to optimize the total cost (collection and transportation cost) of solid waste management for Corporation of Chennai (CoC), the civic body that governs the city of Chennai, the capital of the Indian state of Tamil Nadu. CoC handles about 7 million people's waste disposal, and the waste accounts for 4,841 tonnes per day. We present a mathematical model, followed by a heuristic approach for the deterministic waste-generation scenario, and a simulation-optimization model for the stochastic waste-generation scenario. The models serve to address the issue of allocation and routing of trucks for waste pickup, and delivery to transfer stations, and thereafter to dumping yards.

## ■ TD82

Hyatt, Phoenix West

**Health Care IV**

Contributed Session

Chair: Xu Zhang, University of Maryland, 4176 Campus Drive, William E. Kirwan Hall, College Park, MD, 20742, United States

### 1 - Multi-appointment Outpatient Scheduling for Cardiology Programs

Lida Aperi, University of Maryland, 8223 Paint Branch Drive, 2243 AV Williams, ISR, College Park, MD, 20742, United States, John Baras, Bruce L. Golden, Kenneth Wood

This research tackles the problem of multi-appointment scheduling of outpatients going through elective programs in cardiology. The patients have to visit the hospital multiple times in order to complete the required tests and treatments before the final procedure. A model is developed towards optimizing the allocation of the available resources to the patients. The objective is to minimize the number of visits that the patients have to make to the hospital. A stochastic integer programming formulation is developed to optimize the scheduling decisions over time.

### 2 - Resilience as a Measure of Preparedness for Pandemic Influenza Outbreaks

Walter Alejandro Silva-Sotillo, University of South Florida, 4202 E. Fowler Ave, Tampa, FL, 33620, United States

Since spring 2013, periodic emergence of avian influenza A(H7N9) virus in China has heightened concerns for a possible pandemic outbreak, though it is believed that the virus is not yet human-to-human transmittable. From a public health preparedness standpoint, it is essential to assess the possible impact of an Influenza pandemic and to measure resilience: the ability to recover after such potential pandemic. The aim of this research is to measure the level of resilience that a given population could face in case of a potential Influenza Outbreak happens.

### 3 - Partition-based Simulation Optimization Algorithms for Primary Care Panel Management

David Desmond Linz, Graduate Student Researcher, University of Washington, Seattle, WA, 98105, United States, Zeld B. Zabinsky, Paul Fishman

When designing primary care panel composition, decision-makers need to balance a number of concerns including patient load, travel times for patients, and accommodating the demand for virtual care. To model primary care systems, a discrete event simulation is developed. To best determine paneling policy, we explore the application of several new partition based algorithms that are designed to explore a high-dimensional problem domain to locate good policy solutions. We compare solutions generated by the optimizers in terms of policy impacts and comment on the relative effectiveness of the optimizers in higher dimensions.

### 4 - A Reliability-based Approach for Performance Optimization of Service Industries: An Application to Healthcare Systems

Hossein Badri, Wayne State University, 4815 4th Street, Manufacturing Building, Detroit, MI, 48202, United States, Taha-Hossein Hejazi, Kai Yang

This study aims to apply the Multi-Response Optimization (MRO) method for reliability-based performance optimization of healthcare systems. In this study, we consider all types of response variables so that strength features of the system are optimized against external stresses. The proposed approach in this research is based on the stress-strength model, and stresses are assumed to be normally distributed. Also, we present the implementation results of the proposed approach to a hospital in Iran for reliability-based optimization of the bed capacity planning. The results indicate that the proposed approach is very powerful in tackling the inherent complexity of healthcare systems.

### 5 - Evaluating Appointment Postponement in Scheduling Patients at a Diagnostic Clinic

Mahsa Kiani, Clemson University, Clemson, SC, 29631, United States, Burak Eksioglu, Tugce Isik

In today's healthcare system, the increase in requests for doctors combined with a shortage of physicians has led to challenges for clinics to give timely appointments to patients. In this study, we propose a postponable acceptance model for scheduling different priorities patients to decrease indirect waiting time of higher priority patients (the time between the day the patient requests an appointment and the appointment day). Higher priority patients receive appointment upon arrival. However, the decision regarding accepting and assigning an appointment to lower priority patients is postponed. By postponing these requests and waiting for more urgent patients the profit is increased.

### 6 - A Continuous-time Markov Model for Estimating Readmission Risk for Hospital Inpatients

Xu Zhang, University of Maryland, College Park, MD, United States, Sean Barnes, Bruce Golden, Paul Smith

Research concerning hospital readmissions has mostly focused on regression models that include various factors that influence the likelihood of this unfortunate outcome. These models are useful in certain settings, but their performance in many cases is lacking, and the dynamics of how readmission risk changes over time is often ignored. Our goal is to develop a model for readmission risk over time—using a continuous-time Markov chain—beginning at the point of discharge. We derive point and interval estimators for readmission risk. Finally, we validate our derived estimators using simulation, and apply our methods to estimate readmission risk over time using discharge and readmission data.

## ■ TD83

Hyatt, Remington

**Practice- Health Care IV**

Contributed Session

Chair: Ting Wu, Nanjing University, Department of Mathematics, No 22 Hankou Road, Nanjing, 210093, China

### 1 - Analyzing Alternative Doctor to Room Ratio in an Outpatient Clinic as a Means of Improving Overall Patient Access

Qing Wen, University of Pittsburgh Department of Engineering, Pittsburgh, PA, United States, Louis Luangkesorn, Anna Svirsko, Jay Rajgopal

Children's Hospital of Pittsburgh hosts a number of specialty outpatient pediatrics clinics. Currently, the space available is believed to be a constraint in the overall capacity for outpatient appointments. One way to increase capacity is to reduce the ratio of rooms to doctors. However, that creates a risk that the doctor's time will not be as productive due to waiting for patients and rooms to be prepped and cleaned. We develop a simulation to compare the effect of different room to doctor assignment patterns in doctor productivity and throughput. We also use this as part of a larger simulation that models the effect of increased capacity on the patient backlog for the clinic.

### 2 - A Discrete-event Simulation Model to Optimize Emergency Department Wait Times and Inpatient Unit Flow at an Academic Medical Center

Gokhan Kirlik, University of Maryland Medical System, 920 Elkridge Landing Rd, Linthicum Heights, MD, 21090, United States, Bill Bame, Kenneth Wood, Warren D'Souza

A discrete-event simulation model is developed to improve the flow of patients from the emergency department (ED) through the inpatient setting at a tertiary/quaternary academic medical center. After comprehensive analysis of electronic medical records (EMR), the main inputs of the model, which include ED arrivals, patient flow in ED, direct admissions, hospital inpatient unit flows, length of stay, discharges and bed/room cleaning are obtained. Validation and verification of the simulation model against EMR confirmed that the model mimics the real-world observations accurately. This model will serve as a reliable test bed for hospital operations improvement initiatives.

### 3 - Accelerating Kidney Allocation: Simultaneous and Expiring Offers

Michal Mankowski, King Abdullah University of Science and Technology, Thuwal, Saudi Arabia, Sommer Gentry

After the new Kidney Allocation System (KAS) began, the kidney discard rate increases, especially for marginal quality kidneys. Placing non-ideal organs quickly might increase utilization by decreasing discards. We simulated making simultaneously expiring offers to multiple centers, where every center must accept or decline within the same 1 hour. Simultaneously expiring offers would burden centers to evaluate offers that might otherwise never have come to their center. We also estimated additional workload caused by one new allocation scheme.

### 4 - Prioritization Between Boarding Patients and Patients Currently Waiting or Under Treatment in the Emergency Department

Kim De Boeck, KU Leuven, Leuven, Belgium, Ra sa Carmen, Nico Vandaele

The extra workload introduced by boarding patients is a major concern in emergency departments. Not in the least because this confronts the physicians with a challenging task; making a prioritization decision between boarding patients and patients currently under treatment in the emergency department. The main contribution of this paper is the examination of different control policies for the physicians when needy boarding patients are added to the analysis. Using discrete-event simulation, three static priority policies and one dynamic priority policy are evaluated on various performance measures.

### 5 - A Discrete-event Simulation Approach for Modeling Human Body Glucose Metabolism

Buket Aydas, University of Wisconsin-Milwaukee, 3200 N. Crammer St., Milwaukee, WI, 53211, United States, Mukul Goyal

This study describes CarbMetSim, a discrete-event simulator that tracks the blood glucose level of a person in response to a timed sequence of diet and exercise activities. CarbMetSim implements broader aspects of carbohydrate metabolism in human beings with the objective of capturing the average impact of various diet/exercise activities on the blood glucose level. Key organs are implemented to the extent necessary to capture their impact on the production and consumption of glucose. Key metabolic pathways are accounted for by using the published values of the average flux along these pathways in the operation of different organs. CarbMetSim has the ability to model different levels of diabetes.

### 6 - Verify an Anesthesia Approach for the Target Blood Volume Control

Ting Wu, Nanjing University, Department of Mathematics, No 22 Hankou Road, Nanjing, 210093, China, Cheng Zhu

Anesthesia is an inevitable and critical procedure during an operation, resulting in the amount of blood loss directly. This study verifies a typical anesthesia approach for liver surgeries, which can reach the target blood volume control, through simulation models. We provide clinical guidelines for training anesthetists and evaluating their performance.

## ■ TD84

Hyatt, Russell

### Practice- Innovation/ Entrepreneurship II

Contributed Session

Chair: Ping Deng, University of Science and Technology of China, No.96, Hefei, 230026, China

#### 1 - Rights of First Negotiation and Rights of First Refusal in New Product Development Partnerships

Guangyu Wan, Assistant Professor, Hunan University, #724, Admin Building, North Campus, Changsha, 410006, China, Bhattacharya Shantanu, Sameer Hasija, Niyazi Taneri

Strategic control rights such as the right of first negotiation (ROFN) and the right of first refusal (ROFR) are commonly used in the pharmaceutical industry for creating partnerships between biotech and pharmaceutical firms. We build a stylized principal-agent model to study the contract design problem with the ROFN and ROFR. We investigate the efficacy of different control rights being offered from the innovator's (biotech firm) perspective. We also investigate the role of strategic control rights in resolving the adverse selection problem for the innovator. Our results address an important issue, viz., which control right to offer under which circumstances.

#### 2 - Economies Before Scale: Learning, Survival, and Productivity of Young Plants in the Age of Cloud Computing

Wang Jin, Research Associate, MIT, Cambridge, MA, United States, Kristina Steffenson McElheran

Young firms are central to productivity and growth, yet they fail at high rates. Recent advances in how firms access information technology (IT) - in particular, cloud computing - have dramatically lowered the costs of learning about productivity-enhancing IT. Using Census Bureau data from 2006 to 2014, we find that young-plant failure rates fell 5% due to new IT services, while traditional IT proved risky. Conditional on survival, young plants enjoy much higher cloud-related productivity gains compared to older ones. We provide the first large-scale evidence concerning both the magnitude of and mechanisms behind cloud-driven productivity growth in the U.S.

#### 3 - New Knowledge Availability, Intellectual Property Right Regimes and Technology-based Entrepreneurship in China

Ping Deng, PhD Candidate, University of Science and Technology of China, Hefei, China, Jin Hong

This study empirically investigates the contextual influence of intellectual property protection (IPR) on the use of new available knowledge by entrepreneurs in China's high-tech industry. Using a unique database of China's high-tech new formations from 2000 to 2008, we show that higher level investment in new knowledge is critical in encouraging creating high-tech ventures. However, stronger enforcement of IPRs negatively affects new knowledge availability. Industry heterogeneity analyses show that the need of IPR protection varies by industries. These findings contribute to understanding the influence of IPR protection on the technology-based entrepreneurial behavior in China.

## Tuesday, 3:40PM - 4:30PM

### ■ Keynote – Tuesday

West Bldg 301AB

#### Keynote: Operational Innovation to Profitably Achieve Net Negative CO2 Emissions

Keynote Session

Chair: Ali E. Abbas, University of Southern California, Los Angeles, CA, 90089, United States

#### 1 - Operational Innovation to Profitably Achieve Net Negative CO2 Emissions

Erica Plambeck, Stanford University, Stanford, CA, 94305-7298, United States

Operational innovation in the construction industry and the palm oil industry could increase profitability and reduce the CO2 emissions associated with those industries (perhaps even to net negative levels), and thus substantially reduce global anthropogenic CO2 emissions. I will describe new teaching materials and research that illustrate these hopeful prospects.

### ■ Keynote – Tuesday

West Bldg 301D

#### Keynote: Franz Edelman Award FCC

Emerging Topic: Keynote

Emerging Topic Session

Chair: Anne G. Robinson, Verizon Wireless, Basking Ridge, NJ, 07920, United States

#### 1 - FCC Edelman Reprise

Karla L. Hoffman, George Mason University, Fairfax, VA, 22030, United States, khoffman@gmu.edu

The Federal Communications Commission (FCC) recently completed the world's first two-sided spectrum auction, reclaiming spectrum from TV broadcasters to meet exploding demand for wireless services. Operations research tools- including optimization, simulation, and SAT-solvers - were essential to both the design and implementation of the auction. The auction was one of the most successful in the FCC's history, repurposing 84 MHz of spectrum and generating revenue of nearly \$20 billion, including more than \$10 billion in new capital for the broadcast TV industry and over \$7 billion to pay down the U.S. deficit.

### ■ Keynote – Tuesday

West Bldg 301C

#### Keynote: Wagner Prize Winner

Emerging Topic: Keynote

Emerging Topic Session

Chair: Patricia Neri, SAS Institute, Inc., Cary, NC, 27519, United States

#### 1 - Wagner Prize

Patricia Neri, SAS Institute, Inc., Cary, NC, 27519, United States

The Daniel H. Wagner Prize is awarded for a paper and presentation that describe a real-world, successful application of operations research or advanced analytics. The prize criteria emphasize innovative, elegant mathematical modeling and clear exposition.



**Tuesday, 4:35PM - 6:05PM**

## ■ TE01

North Bldg 121A

### **Distributionally Robust Optimization**

Sponsored: Optimization/Optimization Under Uncertainty

Sponsored Session

Chair: Grani Adiwena Hanasusanto, The University of Texas at Austin, Austin, TX, 78712, United States

#### **1 - A Data-driven Distributionally Robust Optimization Approach for Appointment Scheduling with Random Service Durations and No-shows**

Guanglin Xu, University of Minnesota, Minneapolis, MN, 55108, United States, Ruiwei Jiang

We study a single-server appointment-scheduling problem where the number of appointees and the sequence of their arrivals are fixed. The service durations and appointees' show-ups are stochastic, but the true probability distribution is unknown. With a collection of historical data, we propose a data-driven distributionally robust optimization model, which minimizes the worst-case total expected cost, by optimizing the scheduled arrival times of the appointees. We reformulate the resulting problem into a copositive program and discuss tractabilities under mild conditions. We then develop a tight semidefinite-programming-based approximation and validate it on benchmark instances.

#### **2 - Distributionally Robust Optimization with Infinitely Constrained Ambiguity Sets**

Melvyn Sim, National University of Singapore, 15 Kent Ridge Building, Biz1 8-76, Singapore, 119245, Singapore, Huan Xu, Zhi Chen

We propose a new class of infinitely constrained ambiguity sets for which the number of expectation constraints could be infinite. The description of such ambiguity sets can incorporate the stochastic dominance, the dispersion, the fourth moment, and our newly proposed "entropic dominance information about the uncertainty."

#### **3 - A Copositive Approach for Multi-stage Robust Optimization Problems**

Grani A. Hanasusanto, The University of Texas at Austin, Austin, TX, 78712, United States, Guanglin Xu

In this talk, we study generic multi-stage linear robust optimization problems. We employ affine decision rules for problems with both uncertain objective coefficients and recourse matrices, and utilize quadratic decision rules for problems with only uncertain right-hand sides. The emerging optimization problems are NP-hard but amenable to copositive programming reformulations that give rise to tight conservative approximations. We provide both theoretical and numerical results to demonstrate the effectiveness of the copositive programming approach.

#### **4 - On the Heavy-tail Behavior of the Distributionally Robust Newsvendor Model**

Karthik Natarajan, Singapore University of Technology and Design, Singapore University of Technology and Design, 20 Dover Drive, Singapore, 138682, Singapore, Bikramjit Das, Anulekha Dhara

Since the seminal work of Scarf (1958) on the newsvendor problem with ambiguity in the demand distribution, there has been a growing interest in the study of the distributionally robust newsvendor problem. A simple observation indicates that the optimal order quantity in Scarf's model for any possible value of the critical ratio is also optimal for a censored student-t distribution with degrees of freedom parameter 2 that has infinite variance. In this paper, we generalize this heavy-tail optimality property to the case when information on the first and the  $n$ th moment is known for any real number  $n > 1$ .

## ■ TE02

North Bldg 121B

### **Two-Stage Stochastic Mixed-Integer Programming**

Sponsored: Optimization/Optimization Under Uncertainty

Sponsored Session

Chair: Yingqiu Zhang, Virginia Tech, Blacksburg, VA, 24060, United States

#### **1 - Markov Decision Processes Under Parameter Uncertainty with a Chance-constrained Programming Approach**

Merve Merakli, University of Washington, Simge Kucukyavuz

In classical Markov Decision Processes (MDPs), action costs and transition probabilities are assumed to be known, although an accurate estimation of these

parameters is often not possible in practice. This study addresses MDPs under cost and transition probability uncertainty with the aim of obtaining policies which optimize the Value-at-Risk associated with the expected performance of an MDP model in terms of parameter uncertainty. Considering a sampling approach, we provide a mixed-integer programming formulation and a branch-and-cut algorithm. Our proposed methods are demonstrated on an inventory management problem for humanitarian relief operations during a slow onset disaster.

#### **2 - Two-stage Distributionally Robust P-order Conic Mixed Integer Programs**

Yingqiu Zhang, Virginia Tech, 305 Loudon Rd #631, Blacksburg, VA, 24060, United States

We present two-stage distributionally robust p-order conic integer programs (TSDR-CMIPs) in which the second-stage problems have p-order conic constraints along with integer variables. We provide sufficient conditions under which the integrality constraints on the second-stage integer variables can be relaxed, without affecting the integrality of the optimal solution, by adding parametric (non)-linear inequalities. We introduce structured CMIPs in the second stage of TSDR-CMIPs, derive inequalities which satisfy the foregoing conditions, and present results of our extensive computational experiments for  $p=2$ .

#### **3 - SIPLIB 2.0: Stochastic Integer Programming Library 2.0**

Yongkyu Cho, Pohang University of Science and Technology, Pohang, Korea, Republic of, Kibaek Kim, James Luedtke, Jeff T. Linderoth

SIPLIB was constructed in 2002 by Shabbir Ahmed and his colleagues. The library has been providing a collection of test instances to facilitate computational and algorithmic research in SIP. State-of-the-art in SIP combined with the speedup in computing machinery, however, has made many SIPLIB instances trivial. By SIPLIB 2.0, we provide 1) richer collection of test instances with benchmarking computational results, 2) not only SMPs files but also utilities for generating/analyzing instances. SIPLIB 2.0 is implemented in Julia programming language with modeling package StructJuMP (block-structured optimization framework for JuMP).

#### **4 - Generalized Alpha-approximations for Mixed-integer Recourse Models**

Ward Romeijnnders, University of Groningen, Groningen, Netherlands, Niels van der Laan

We consider generalized alpha-approximations for two-stage mixed-integer recourse models. They are a generalization of a class of convex approximations developed for simple integer recourse models and totally unimodular integer recourse models. We derive an error bound for these generalized alpha-approximations that converges to zero if the total variations of the probability density functions of the random variables in the model converge to zero.

## ■ TE03

North Bldg 121C

### **Innovative Business Models and Bottom of the Pyramid**

Sponsored: Manufacturing & Service Oper Mgmt

Sponsored Session

Chair: Serguei Netessine, The Wharton School, Philadelphia, PA, 19104, United States

Co-Chair: Bhavani Shanker Uppari, INSEAD, Singapore, 138676, Singapore

#### **1 - Disruptions, Resilience and Performance of Emerging Market Entrepreneurs: Evidence from Uganda**

Amrita Kundu, PhD Candidate, London Business School, London, United Kingdom, Stephen J. Anderson, Kamalini Ramdas

We examine the effect of firm-specific business disruptions (both managerial and operational) on the performance of small firms in emerging markets and the effectiveness of appropriate resilience strategies in buffering against these disruptions. Using a hand-built panel dataset on 646 small firms over four time periods in Kampala, Uganda, we find that disruptions are highly prevalent and have a statistically and economically significant effect on the performance of these firms. Importantly, we find that both relational and resource resilience significantly help buffer against the negative impact of managerial and operational disruptions, respectively.

## 2 - Impact of Inconvenience and Liquidity Constraints on the Usage of Off-grid Solutions: Evidence from Rwanda

Bhavani Shanker Uppari, INSEAD, 1 Ayer Rajah Avenue, Singapore, 138676, Singapore, Serguei Netessine, Ioana Popescu, Rowan Clarke, Manuel Barron, Martine Visser

One-fifth of the world's population does not have access to electricity. Solar-based solutions are unaffordable in these markets due to consumers' poverty. There are alternative business models relying on rechargeable light bulbs (sold at a subsidized price) which require regular payments for recharges. We investigate the viability of these recharge-based models under poverty. In collaboration with a firm in Rwanda, we collected the bulb usage data from randomized experiments wherein the price and the bulb capacity were varied. We also build a structural model that incorporates the light consumption dynamics, and use it to evaluate theoretically-preferred changes to the existing model.

## 3 - Monitoring in Public Sector Supply Chains and the Role of Technology

Maya Ganesh, Indian School of Business, Hyderabad, India, Sarang Deo, Sripad K. Devalkar

We examine the impact of installation of point-of-sale (POS) devices at fair-price-shops (FPS) on leakages. Using a quasi-experimental difference-in-difference approach along with the technique of propensity score matching, we estimate an average monthly reduction of 44 kgs in leakage of rice per FPS. Our results suggest that investing in technology-based monitoring mechanisms can improve performance of public sector supply chains and create economic value even without changing the contracting between channel players. We further conduct a simulation study to estimate the potential value of information of using the real time information provided by POS devices for better decision making.

## 4 - Rent-to-Own Business Models in Developing Economies: An Empirical Analysis

Jose A. Guajardo, University of California-Berkeley, Haas School of Business, 545 Student Services Bldg, Berkeley, CA, 94720-1900, United States

Rent-to-Own business models have become popular for the diffusion of energy products in developing economies, as they provide the flexibility to make incremental payments that eventually lead to product ownership by low-income consumers. I empirically analyze consumer behavior in rent-to-own environments in the context of distribution of solar lamps in Sub-Saharan Africa, characterizing different factors that influence operational performance.

## TE04

North Bldg 122A

## Advances in Theory and Practice of Location Science

Sponsored: Optimization/Integer and Discrete Optimization

Sponsored Session

Chair: Manish Bansal, Virginia Tech., Blacksburg, VA, 24060, United States

## 1 - Locating Drone Platforms for Delivering Medical Supplies with Time Costs

Pitu B. Mirchandani, Arizona State University, School of Computing, Informatics and Decision System, Tempe, AZ, 85287, United States, Monica Gentili, Alessandro Agnetis

In this paper, we consider a drone delivery problem that could potentially create a significant improvement in terms of cost and time required for providing essential medical supplies. In particular, we consider first the case when we study the problem of sending perishable items in a single day to demand points where cost of delivery depends not only on the time of delivery but also on a soft delivery due date. Other cases are studied where delivery may take place over several days and when platforms can be moved from day to day.

## 2 - Planar Maximum Coverage Location Problem with Partial Coverage and General Spatial Representation of Demand and Service Zones

Manish Bansal, Virginia Tech., 227 Durham Hall, 1145 Perry Street, Blacksburg, VA, 24060, United States

We present a new generalization of the planar maximum coverage location problem in which demand and service zones are represented by spatial objects such as circles, polygons, etc., and are allowed to be located anywhere in a continuous plane. We allow partial coverage in its true sense, i.e., covering only part of a demand zone is allowed and the coverage accrued in the objective function as a result of this is proportional to the demand of the covered area only. We present a greedy algorithm and a pseudo-greedy algorithm for it, and showcase that the solution value corresponding to the greedy solution is within a factor of  $1 - 1/e$  of the optimal solution value where  $e$  is the base of natural logarithm.

## 3 - Design and Operation of Renewable Hybrid Energy Systems

Alexandra M. Newman, Colorado School of Mines, 1500 Illinois St, Golden, CO, 80401, United States, Alex Zolan, Michael S. Scioletti, Mark Husted, Gavin Goodall

Renewable energy technologies, specifically, solar photovoltaic cells, combined with battery storage and diesel generators, form a hybrid system capable of independently powering remote locations, i.e., those isolated from larger grids. If sized correctly, hybrid systems reduce fuel consumption compared to diesel generator-only alternatives. We present an optimization model for establishing a hybrid power design and dispatch strategy, solution techniques for this mixed-integer, nonlinear model, and insights and extensions.

## TE05

North Bldg 122B

## Joint Session OPT/Practice Curated: Recent Developments and Applications using Julia for Optimization

Sponsored: Optimization/Computational Optimization and Software  
Sponsored Session

Chair: Joey Huchette, MIT, Cambridge, MA, 02139, United States

## 1 - Infrastructure Optimization in Julia

Carleton Coffrin, Los Alamos National Laboratory, Los Alamos National Laboratory, Los Alamos, NM, United States

The significant penetration of distributed renewable energy resources and increasingly dynamic fuel prices present significant challenges for the design and operation of critical infrastructure systems. To help explore how optimization algorithms can address these emerging challenges this work presents a collection of Julia packages for infrastructure optimization. These packages provide a variety of tools for, reproducing state-of-the-art results, developing new problem formulations, and benchmarking novel algorithms using standardized data formats and test cases.

## 2 - Mixed-integer Programming in Julia: From Formulations to Modeling to Algorithms

Joey Huchette, MIT, 77 Massachusetts Avenue, Cambridge, MA, 02139, United States

In this talk we show how a variety of tools in the Julia programming language can be used throughout the optimization pipeline. First, we present how computational tools can be used to build MIP formulations: by guiding intuition, but also in a completely automated fashion. Next, we present modeling tools for piecewise linear functions that showcase how a high-level interface can help make advanced techniques more accessible to researchers and practitioners. Finally, we show how to use Julia to customize modern MIP solvers to implement advanced and experimental MIP algorithms.

## 3 - POD.jl: A Global, Mixed-integer Nonlinear Programming Solver in Julia

Kaarthik Sundar, Bryan, TX, 77801, United States

Non-convex, mixed-integer nonlinear programs (MINLPs) are hard optimization problems to solve to global optimality. State-of-the-art global solvers, such as BARON, Couenne, and SCIP, often handle MINLPs using the spatial branch-and-bound approach in combination with various other tools. However, there has recently been a great deal of interest in MILP-based approaches for solving MINLPs that are based on piecewise convex relaxations. In this work, we present a MILP-based global solver for MINLPs, named POD, where the name represents the three key solution techniques to solve MINLPs: Piecewise convex relaxations (P), Outer-approximation (O), and Dynamic partitioning (D).

## 4 - Modeling and Solving Mixed-integer Nonlinear Optimization Problems in Julia

Christopher D. Coey, Massachusetts Institute of Technology, Cambridge, MA, 02139, United States, Juan Pablo Vielma

We use real-world decision problems to illustrate the convenient modeling power of JuMP ([github.com/JuliaOpt/JuMP.jl](https://github.com/JuliaOpt/JuMP.jl)) for mixed-integer nonlinear optimization. We demonstrate how to access a variety of solvers, including our next-generation mixed-integer conic solver Pajarito ([github.com/JuliaOpt/Pajarito.jl](https://github.com/JuliaOpt/Pajarito.jl)). Pajarito is written in Julia and uses a primal-dual continuous conic solver (such as Mosek) and a mixed-integer linear solver (such as CPLEX) to perform conic-certificate-based outer approximation.

## 5 - Mixed-integer Convex Representability

Juan Pablo Vielma, Massachusetts Institute of Technology, 77 Massachusetts Avenue, E62-561, Cambridge, MA, 02139, United States, Miles Lubin, Ilias Zadic

We consider the question of which nonconvex sets can be represented exactly as the feasible sets of mixed-integer convex optimization problems (MICP). We first show a complete characterization for the case when the number of possible integer assignments is finite. We then further study the characterization for the more general case of unbounded integer variables and introduce a simple necessary condition for representability. We illustrate these characterizations through various examples of sets that can or cannot be modeled as MICP.

## ■ TE06

North Bldg 122C

**Joint Session OPT/Practice Curated: Network Optimization in Applications**

Sponsored: Optimization/Global Optimization

Sponsored Session

Chair: Golshan Madraki, PhD, Clarkson University, Potsdam, NY, 13699, United States

**1 - Most Closeness Central Clique Problem**Farzaneh Nasirian, University of Massachusetts-Boston,  
100 William T. Morrissey Blvd, Boston, MA, 02125, United States,  
Foad Mahdavi Pajouh

This talk addresses the most closeness-central clique problem in which we are interested in detecting a most accessible clique in a graph. We use two metrics of maximum and total distance to a clique for measuring its accessibility resulting in two variants of the most closeness-central clique problem. For each of these two problems, we address the computational complexity, develop a new mixed 0-1 integer programming formulation, and propose the first combinatorial branch-and-bound algorithm. The computational performance of these exact algorithms is studied on a test-bed of real-life instances.

**2 - Information Based Drone Assisted Parcel Delivery in Urban Environments**Cesar N. Yahia, The University of Texas at Austin, Austin, TX,  
78705, United States, Can Gokalp, Prashanth Venkatraman,  
Stephen D. Boyles

We investigate the problem of using unmanned aerial vehicles alongside a truck for last-mile parcel delivery in an urban environment. The objective is to determine the route that the truck should traverse as well as the locations where the drone should be deployed to minimize total truck travel time. We propose real-time algorithms that exploit the travel time estimation capabilities of the drone.

**3 - On the Structure of Potential Driven Networks**Gerrit Slevogt, Universit t Duisburg-Essen, Ruediger Schultz,  
Sabrina Nitsche

Potential driven networks such as water, gas and power are core utilities of today's world. They are governed by specific (non-linear) constraints such as derivatives of the Euler equations in gas and water and Kirchhoff's circuit laws in power networks. Especially in power networks the rise of renewable energies is driving the expansion and meshing of networks. Thus, the problem of finding operational bounds on the supported input-output nominations is getting more complex. Finding optimal controls or flows on a case by case basis is operationally feasible but unsatisfying. An analysis of the structure of such networks and arising properties can lead to a more comprehensive view of such networks.

**4 - Accelerating the Scheduling Improvement Heuristics by Finding the Longest Path in the Perturbed Graph**

Golshan Madraki, Clarkson University, Potsdam, NY, USA

Scheduling improvement heuristics iterate over trial schedules to determine a satisfactory schedule. During each iteration, a performance measure (e.g., makespan) is calculated. This research presents an efficient algorithm, Structural Perturbation Algorithm (SPA), that accelerates the calculation of makespan. This means all scheduling improvement heuristics using SPA to calculate makespan for each trial schedule will run faster. We model the manufacturing by a Directed Acyclic Graph (DAG). Schedule trials are represented by perturbed DAGs where multiple edges are added and deleted. SPA can handle multiple edge deletions/additions through a single pass which improves the time complexity in comparison with current approaches.

## ■ TE07

North Bldg 123

**Joint Session OPT/Practice Curated: Network Optimization Models for Transportation**

Sponsored: Optimization/Network Optimization

Sponsored Session

Chair: Ayca Altay, Rutgers University, 110 Washington Rd, Princeton, NJ, 08540, United States

**1 - Midas Proactive Traffic Control; Autonomous Intersection & Diamond Interchange**Viswanath Potluri, Research Associate, Arizona State University,  
Tempe, AZ, 85281, United States

MIDAS proactive traffic control uses forward recursion Dynamic Programming (DP) approach with efficient data structures, over a finite-time horizon that rolls forward and, then uses a backward recursion to retrieve the optimal decision sequence. MIDAS architecture uses vehicle GPS data, queue estimation models

along with DP framework to optimally manage traffic along diamond interchange corridor. MIDAS proactive control is extended to autonomous vehicular traffic, which optimally schedules vehicle movements and manages platoons (by controlling leader and followers).

**3 - Comprehensive and Quantitative Analysis of the Coordination Between Urban Railway and City**Yong Yin, Southwest Jiaotong University, Chengdu, China  
National United Engineering Laboratory of Integrated and  
Intelligent Transportation, Chengdu, China, Jie Liu, Qiyuan Peng,  
Xu Yan, Anjun Li

Evaluating the coordination between urban railway and the city correctly and comprehensively is of great significance for urban railway construction and city development. Based on the fractal theory, the coordination index of urban railway network and urban road network and the coordination index of urban railway station and urban traffic demand were constructed from aspects of multi radius and multi direction. Then, the comprehensive coordination index of urban railway and city was established based on fractal dimension consistency and vector similarity. The research has a certain significance in guiding urban railway planning and improving the coordination between urban railway and city.

**4 - Evolvement of Public Charging Infrastructure in a Competitive and Stochastic Market**Zhaoimiao Guo, University of Central Florida, 6566 Tealwood  
Drive, Orlando, FL, United States, Julio Deride, Yueyue Fan,  
Yueyue Fan

This paper presents a network-based multi-agent optimization model for strategic planning of charging facilities in a competitive and stochastic market. We provide a solution method based on alternating direction method of multipliers (ADMM).

**5 - Transit Network Design with Congested Common Lines**David Z.W. Wang, Associate Professor, Nanyang Technological  
University, 50 Nanyang Avenue, Singapore, 639798, Singapore

This study focuses on a continuous transit network design problem with explicit consideration of congested common-lines. A tri-level programming model is presented to formulate the problem. Basically, the upper-level program optimizes the transit service frequencies to achieve the objective of both operators and transit users; the middle-level problem describes the passengers' routing choices, which is indeed an equilibrium transit assignment problem; the lower-level program formulates the congested common-line problem. The tri-level model is reduced into an equivalent single level program to be solved. The global optimal solution of the problem is to be obtained.

**6 - Inspection Based Predictive Maintenance for Railways**Ayca Altay, Rutgers University, 640 Bartholomew Rd, Piscataway,  
NJ, 08854, United States, Pedro Cesar Lopes Gerum, Melike  
Baykal-Gursoy

Maintenance activities are essential to preserve safety and cost-effectiveness in railways. The related literature evaluates preventive and corrective maintenance conditions. However, the maintenance activities involve a structured policy of inspections, whose outcomes shape the replacement decisions. This study provides a holistic approach by integrating the prediction of rail and geometric defects, together with the scheduling of inspection-driven maintenance activities. Results indicate a high accuracy rate in prediction and an efficient scheduling structure.

## ■ TE08

North Bldg 124A

**Stochastic First-order Methods**

Sponsored: Optimization/Nonlinear Programming

Sponsored Session

Chair: Farzad Yousefian, Oklahoma State Univeristy, Stillwater, OK,  
74074, United States**1 - Distributed Algorithms for Stochastic Nash Games**Jinlong Lei, Pennsylvania State University, 310 Leonhard Building,  
University Park, PA, 16803, United States, Uday Shanbhag

We consider the development of distributed variable sample-size gradient-response and best-response schemes for structured nonsmooth stochastic Nash games. In each instance, we show that when batch-sizes grow at suitable rates and with sufficient number of consensus rounds, the schemes display linear rates of convergence. Additionally, we quantify the iteration complexity of each scheme.



## 2 - A First Order Method for Stochastic Variational Inequalities on Semidefinite Matrix Spaces

Nahidsadat Majlesinasab, Oklahoma State University, Stillwater, OK, United States, Farzad Yousefian, Mohammad Javad Feizollahi

Motivated by multiuser noncooperative Nash games in stochastic regimes, we consider stochastic variational inequality problems (SVI). While the literature of variational inequality (VI) has focused on vector spaces, there is not enough guidance on solution methods for addressing SVIs on semidefinite matrix spaces. Motivated by this gap, we develop a stochastic mirror descent method. Our contribution is three-fold: (i) employing averaging techniques, we show the generated iterate converges to a weak solution of the SVI; (ii) we derive a convergence rate in terms of the expected value of a gap function; (iii) we implement the method for solving a MIMO throughput maximization problem.

## 3 - An Iterative Regularized Mirror Descent Method for Illposed Nondifferentiable Stochastic Optimization

Mostafa Amini, Oklahoma State University, Stillwater, OK, United States, Farzad Yousefian

A wide range of big data applications result in optimization problems that are often illposed. To address such problems, we consider a model, where the goal is to find an optimal solution that attains the minimum value of a regularizer. We assume the objective function of the main problem and the regularizer are nondifferentiable convex functions, and the main objective is stochastic. We develop an iterative regularized stochastic mirror descent method. We establish the convergence of the iterate generated by the algorithm to the desired optimal solution in both an almost sure and a mean sense, and derive a convergence rate of optimality with respect to the main objective.

## 4 - A First Order Method for High Dimensional Illposed Problems

Harshal Kaushik, Oklahoma State University, 322 Engineering North, Ind, Stillwater, OK, 74078, United States, Farzad Yousefian

We consider high dimensional ill-posed convex optimization problems. To address ill-posedness, we consider minimizing a regularizer over the optimal solution set of a convex optimization problem. We develop a randomized block coordinate iterative regularized gradient method where at each iteration, the stepsize and regularization parameter are updated. We show that the generated sequence converges to the solution of the bilevel problem, and we derive a convergence rate of the order  $d/k^{0.5}$  on the feasibility gap where  $k$  and  $d$  denote the iteration number and number of blocks, respectively. The performance of the algorithm for solving linear inverse problems in image deblurring is presented.

## TE09

North Bldg 124B

### Managing Technology Products across Generations

Sponsored: Manufacturing & Service Oper Mgmt

Sponsored Session

Chair: Charles X. Wang, State University of New York-Buffalo, Buffalo, NY, 14260, United States

Co-Chair: Aditya Vedantam, SUNY Buffalo, Williamsville, NY, 14221, United States

#### 1 - Remanufacturing Competition

Dongmei Xue, Zhejiang University, Hangzhou, China

The competition between firms is growing fierce, especially for the low-end firms. As the profit margin of low-end market decreasing, we provide remanufacturing as a new competition strategy for low-end firms to enter the high-end market. The goal of this paper is to find out how the optimal competition strategy is influenced by the cost structure and customers' valuation. If high-end firm's strategy is given, we show the optimal strategy space is divided into four pieces. Remanufacturing can be a profitable strategy when the cost is lower. Moreover, when high-end firm react to low-end firms' strategy, the optimal strategy space shrink.

#### 2 - Framework for Reducing Technical Debt

Vera Tilson, University of Rochester, 3-343 Carol Simon Hall, W. E. Simon Graduate School of Business, Rochester, NY, 14627, United States, David Tilson

We discuss a framework for reducing technical debt: retiring, outsourcing applications and starting to work on integrated data model to reduce coupling and moving toward "to-be" vision for the long-term architecture.

#### 3 - Supplier Contracting for Reuse at a Third Party Remanufacturer

Aditya Vedantam, State University of New York at Buffalo, 13 Via Pinto Drive, Buffalo, NY, 14221, United States, Ananth V. Iyer

Business users of electronic products often contract with third parties (3PRs) in the secondary market to dispose their equipment at end-of-use. 3PRs provide services such as data security, value recovery and environmental reports to generators. Motivated by an extensive dataset provided by a 3PR, we generate

insights on contracts and drivers of disposition activity for IT equipment in the secondary market. We show how supplier contracts and reuse rates depend on planned replacement activities. Business users can encourage reuse by early planned replacement and modifying contracts. We discuss the environmental impact of planned vs. unplanned equipment replacement.

## 4 - Manufacturer's Mental Accounting and Payment Schemes in Returns Policy

Jun Ru, College of Business Administration, Cal Poly-Pomona, Pomona, CA, United States

Returns policies have been used between the manufacturer and retailer in the distribution of short life-cycle products with uncertain demand. Previous research has shown that returns policies can mitigate the retailer's risk of excess inventory and improve channel performance. This research extends our understanding of returns policies by adopting the concept of mental accounting to describe the manufacturer's behavioral decisions under returns policies. We also investigate two alternative payment schemes (i.e., manufacturer financing and retailer financing) that help mitigate the manufacturer's mental accounting effect in returns policies and improve channel performance.

## 5 - Selling A Technology Product with the Trade-in Program and Used Product Market

Charles X. Wang, State University of New York-Buffalo, Jacobs Management Center, Room 326M, Buffalo, NY, 14260, United States, Imsu Park, Mingcheng Wei

We investigate the manufacturer's optimal strategy for selling a technology product with the trade-in program and used product market. We characterize the interaction between the equilibrium price of the used product market and the trade-in program offered by the manufacturer in the primary market.

## TE10

North Bldg 125A

### Innovative Retail Operations

Sponsored: Manufacturing & Service Oper Mgmt

Sponsored Session

Chair: Hao-Wei Chen, University of Toledo, Toledo, OH, 43615, United States

#### 1 - Cost Auditing in Profit Sharing Contracts

Xiaomin Du, Tsinghua University, Beijing, China, Wanshan Zhu, Zhengping Wu

This study is motivated by profit sharing contracts observed in a supplier-retailer channel, where knowledge of the supplier's true production cost is the key to successful contract implementation. However, production cost is often the supplier's private information, unknown to the retailer. We investigate the role of cost auditing mechanisms in such a setting. While cost auditing enables the retailer to protect his interests, interestingly, we find that the supplier may also benefit from it. We also examine supply chain performance under such mechanisms.

#### 2 - Optimal Information Provision for Undifferentiated Products

Huaqing Wang, Emporia State University, 18923 SW 7th Street, Pembroke Pines, FL, 33029, United States, Haresh B. Gurnani, Raphael Boleslavsky

In this paper, we examine the joint interaction of information provision and pricing decisions by two competitive firms when a buyer is uncertain about product valuations. Firms generate product differentiation by allowing consumers to learn about valuations or prevent them from doing so. In this research, we characterize equilibrium prices and its interaction with information policies.

## 3 - Modeling Retail Store and Online Channel Allocation Decisions for Multiple Items

Roshanak Mohammadivojdan, University of Florida, 303 Weil Hall, P.O. Box 116595, Gainesville, FL, 32611, United States, Joseph Geunes

We consider a multi-product retailer who sells items via both a retail store and an online channel. Retail store shelf space limitations require judicious selection of items that will occupy this valuable space. Moreover, the high relative cost of this space, combined with the availability of a lower cost (in terms of storage-related costs) online channel, force a retailer to determine which items to offer in the store, online, or not at all. The goal of this work is to propose a stylized mathematical program to simultaneously model product assortment and channel allocation decisions, in order to gain insights on key decision drivers and characteristics of optimal decisions.

#### 4 - The Tradeoff Between Landed Price and Return Policy Generosity: Seller versus Buyer Perspectives

Guangzhi Shang, Florida State University, Department of Marketing, College of Business, Tallahassee, FL, 32306, United States, Alan Pritchard, Robert Windle, Philip Evers

Using detailed information on the transaction, product, and seller involved in fixed price (buy-it-now) listings of consumer electronics products from eBay, we estimate the trade-off between landed price and return policy generosity in the online setting. First, the value that online sellers place on a generous return policy is estimated through an evaluation of the prices they charge. Then, buyers' reactions to return policy and price combinations are identified from the time to sale for each listing.

## ■ TE12

North Bldg 126A

### Emerging Topics on Retail Operations

Sponsored: Manufacturing & Service Oper Mgmt

Sponsored Session

Chair: Mehmet Sekip Altug, George Washington University, Washington, DC, 20052, United States

#### 1 - Cause Marketing: Product Pricing, Design, and Distribution

Fei Gao, Indiana University Bloomington, 1309 E. 10th Street, Suite 4100, Bloomington, IN, 47405, United States

Cause marketing (CM) is the practice of donating proceeds from product sales to designated charitable causes. We study the product pricing and design decisions in a CM campaign. We also look at the impact of a decentralized supply chain on the effectiveness of a CM campaign.

#### 2 - Pricing and Assortment Strategies with Product Exchanges

Laura Wagner, NIF 501082522, Lisbon, 1200/830, Portugal  
Laura Wagner, Católica Lisbon School of Business & Economics,  
Católica Lisbon School of Business & Economics, 501082522,  
Lisbon, 1200-830, Portugal, Victor Mart nez de Alb niz

Return policies enable consumers to return /exchange products they are unsatisfied with. We develop a search framework where consumers sequentially learn about products' true value and decide whether to keep, exchange or return them. We show that when pricing is not a decision, the assortment problem does not have a simple structure, but we provide a pseudo-polynomial algorithm to solve it. When pricing is endogenous, the optimization becomes tractable and it is not necessarily optimal to set all products at equal margins. Finally, we find that retailers prefer to pass all return costs on to the consumers, and that this decision can also be beneficial to consumers.

#### 3 - Value of Promotions with Delayed Incentives:

##### An Empirical Investigation of Gift Card Promotions

Bharadwaj Kadiyala, HKUST Business School, Hong Kong,  
Ozalp Ozer, Serdar Simsek

Gift card promotions provide customers an incentive to spend more than an expenditure threshold on regularly priced products, by rewarding customers with a gift card. This type of promotion has become popular among luxury fashion, department, and consumer electronic stores. Using a proprietary data set from a large fashion retailer, we investigate how customers' purchase and expenditure decisions are impacted these promotions as well as the underlying mechanism driving customer response.

#### 4 - Optimal Dynamic Allocation of Sales and Rental Inventory at a Retailer

Mehmet Sekip Altug, George Washington University, 2201 G. Street NW, Funger 415, Washington, DC, 20052, United States, Oben Ceyan

We consider a retailer that simultaneously sells and rents its product over a given horizon. In every period, the retailer faces uncertain demand that splits between renters and buyers based on their utility. We characterize the optimal dynamic rental allocation policy and study its properties. We propose various implementable heuristics. We then extend our results to the duopoly case and characterize the equilibrium. We derive the conditions that lead to "pure sales", "pure rental" or "mixed strategy equilibrium" and discuss their implications.

## ■ TE13

North Bldg 126B

### Emerging Topics in Healthcare Operations

Sponsored: Manufacturing & Service Oper Mgmt/Healthcare Operations

Sponsored Session

Chair: Yuqian Xu, University of Illinois at Urbana-Champaign, Champaign, IL, 61820, United States

#### 1 - The Interplay Between Online Reviews and Physician Demand: An Empirical Investigation

Yuqian Xu, University of Illinois at Urbana-Champaign, Wohlers Hall 487, 1206 S. 6th St, Champaign, IL, 61820, United States, Mor Armony, Anindya Ghose

Social media platforms for healthcare services are changing how patients choose physicians. In this paper, we derive various service-quality proxies from online reviews and study the relationship between these quality proxies and physician demand. To do so, we study a unique data set from one of the leading appointment booking websites in the United States, that contains online physicians' appointments made over a five-month period, along with other online information. We propose a random coefficient choice model to characterize patient heterogeneity in physician choices, taking into account both numeric and textual user-generated content with text mining techniques.

#### 2 - Reducing Hospital Readmissions through Regulation

Tolga Tezcan, London Business School, Regent's Park, London, NW14SA, United Kingdom, Kenan Arifoglu, Hang Ren

We study the effectiveness of Hospital Readmission Reduction Program (HRRP), which was recently introduced by Medicare. Using a game-theoretical stylized model, we find that HRRP may induce excess healthcare cost. We propose a new compensation scheme that results in socially optimal efforts in reducing readmissions.

#### 3 - How Does Multichannel Delivery Impact Access to a Care Network? Evidence from Telemedicine in South India

Kraig Delana, London Business School, Sarang Deo, Kamalini Ramdas

We use data from the Aravind Eye Care System in India to examine how the introduction of rural vision centers equipped with telemedicine impacts patient visit volumes, patient mix, revenues, and outcomes. Using a difference-in-differences model, we find that the introduction of vision centers substantially increases network volumes, largely through new patients. We also find that patients substitute telemedicine visits for hospital visits when appropriate. However, we do not find strong evidence of an increase in treatments (e.g., glasses/cataract surgeries). Our findings highlight the multifaceted impact of the introduction of telemedicine on a multi-channel healthcare delivery network.

#### 4 - Maximizing Intervention Effectiveness

Brian Rongqing Han, University of Southern California, Los Angeles, CA, United States, Vishal Gupta, Song-Hee Kim, Hyung Paek

Without access to the raw data, policymakers often face challenges when deciding whom to receive an intervention previously proven effective. We propose a novel robust optimization framework that uses only causal inference summary data from a published paper to target a subset of the candidate population to maximize intervention effectiveness.

## ■ TE14

North Bldg 126C

### Queues in Services II

Sponsored: Manufacturing & Service Oper Mgmt/Service Operations

Sponsored Session

Chair: Amy R. Ward, University of Southern California, Los Angeles, CA, 90089-0809, United States

Co-Chair: Rouba Ibrahim, University College London, London, WC1E 6BT, United Kingdom

#### 1 - Off-placing Patients in Hospital Wards: The Value of Flexibility in Healthcare

Vahid Sarhangian, University of Toronto, Toronto, ON, Canada, Carri Chan, Yuan Zhong

A common practice in many hospitals is the off-placement of admitted emergency department (ED) patients to a non-primary inpatient ward (IW) when the primary ward is at full capacity. We evaluate and compare the performance of practical flexible designs for routing patients from the ED to IW. We consider a multiclass queueing system with multiple server pools (wards) and allow the

customers to be served by servers from a non-primary pool (determined through the flexible design) with a reduced service rate to capture the effect of off-placement.

## 2 - Design and Pricing of Discretionary Service Lines

Laurens G. Debo, Dartmouth College, 100 Tuck Hall, Hanover, NH, 03755, United States, Cuihong Li

We discuss the optimal offering of a menu of discretionary services, for which longer processing times yield higher quality, but also create more system congestion. We show that prioritizing short services increases the breadth of the menu and that prices may be non-monotone in duration.

## 3 - Queueing and Learning

Costis Maglaras, Columbia University, Graduate School of Business, 3022 Broadway Avenue, New York, NY, 10027, United States, John J. Yao, Assaf Zeevi

Demand systems used in service operations often assume that system parameters that affect user decisions, e.g., to join a system or purchase a service, are known or communicated to the market. In practical settings this need not be the case, but users may still form estimates of these parameters through their own observations. We study the effect of observational learning on user behavior and equilibrium performance in a congested queueing model where delay-sensitive customers with no a priori knowledge of the service rate, join the system and observe their progress through the queue in order to learn the system's service rate, estimate remaining waiting times, and make abandonment decisions.

## 4 - On Personalized Scheduling Disciplines in Queueing Systems: Does Knowing your Customer Matter?

Seyedmorteza Emadi, University of North Carolina-Chapel Hill, 221 Tremont Circle, Chapel Hill, NC, 27516, United States, Rouba Ibrahim, Saravanan Kesavan

The paradigm of personalized queues is becoming increasingly relevant with the availability of customer-specific data in practice. In this work, we focus on the implementation of scheduling policies exploiting individual customer service-time information. By analyzing data from a call center, we quantify the improvement in predictive accuracy resulting from exploiting individual customer history to predict future service times. We quantify the operational impact of using those improved predictions in the scheduling of customers through both direct analysis and a numerical study.

## TE15

North Bldg 127A

### Strategic Queueing in Service Operations

Sponsored: Manufacturing & Service Oper Mgmt/Service Operations

Sponsored Session

Chair: Jianfu Wang, Nanyang Business School, Nanyang Technological University, Singapore, 639798, Singapore

Co-Chair: Shrutivandana Sharma, Singapore University of Technology and Design, 20 Dover Drive, Singapore, 138682, Singapore

## 1 - Evaluating the First-mover's Advantage in Announcing Real-time Delay Information

Siddharth Prakash Singh, Carnegie Mellon University, Tepper School of Business, 5000 Forbes Avenue, Pittsburgh, PA, 15213, United States, Mohammad Delasay, Alan Scheller-Wolf

Advances in internet-based technology have enabled service providers to disseminate real-time delay estimates to customers who are strategic and delay-sensitive. In a market with two service providers who compete for market share, we investigate whether one of the service providers (the technology leader L) should begin to announce her real-time delay information, knowing her competitor (the follower F) could opt to respond. We cast this leader-follower setting as a sequential queueing game. We find that L's delay announcements improve, in equilibrium, her market share when she is not the higher-capacity service provider; otherwise, initiating delay announcements erodes her market share.

## 2 - Queueing Design when Customers Can Balk: Pooled or Dedicated?

Nur Sunar, UNC, 1604 Village Crossing Drive, Chapel Hill, NC, 27517, United States, Yichen Tu, Serhan Ziya

It is generally accepted that operating with a combined (i.e., pooled) queue rather than separate (i.e., dedicated) queues is beneficial mainly because pooling reduces average throughput time in a system. We consider a multi-server queueing system that can be run as a pooled or a dedicated system. Unlike the pooling literature, in our paper, customers are rational, i.e., they decide to join or balk based on queue length information upon arrival. We prove that, in contrast to the general understanding, the dedicated system can result in strictly smaller average throughput time, and strictly larger social welfare than the pooled system; performance degradation due to pooling can be significant.

## 3 - A Model of Queue Scalping

Luyi Yang, Johns Hopkins University, 100 International Drive, Baltimore, MD, 21202, United States, Shiliang Cui

This paper studies a setting in which a queue scalper enters a waiting line only to sell his position later to future arriving customers. The problem is motivated by the business model of a tech company CallEnQ, which applies the idea of queue scalping to helping professionals spend less time waiting on hold to talk to IRS. We find that a higher demand for the underlying queueing system does not translate to a higher revenue for the queue scalper, which implies that when deciding which queue to enter, a queue scalper should not always target high-demand ones. This result extends to a firm operating any finite number of queue scalpers.

## TE16

North Bldg 127B

### Sustainable and Transparent Supply Chains

Sponsored: Manufacturing & Service Oper Mgmt/Sustainable Operations

Sponsored Session

Chair: Christian Blanco, Ohio State University, Columbus, OH, 43210, United States

## 1 - Companies' Contributions to Sustainability through Global Supply Chains

Joann de Zegher, Assistant Professor, MIT Sloan, Cambridge, MA, 02142, United States, Tannis Thorlakson, Eric Lambin

Companies use a variety of Sustainable Sourcing Practices (SSPs) to address social and environmental challenges in their supply chains. Our current understanding of such SSPs is largely based on theoretical models, literature reviews and case studies. We use a random sample of 450 public companies to study the range of SSPs that companies pursue, addressing the following questions. What SSPs do companies adopt? How many tiers in the supply chain do SSPs cover and to what extent are these SSPs audited? What factors explain the type of SSP a company adopts and are these factors in line with theoretical predictions? This research helps direct the research agenda in sustainable supply chain management.

## 2 - Motivating Supplier Social Responsibility under Incomplete Visibility

Leon Valdes, University of Pittsburgh, Joseph M. Katz Graduate School of Business, 119B Mervis Hall, Pittsburgh, PA, 15260, United States, Tim Kraft, Yanchong Zheng

We study a manufacturer's decisions when the social responsibility (SR) performance of her supplier cannot be perfectly observed. Only the supplier can directly impact SR; the manufacturer can: (i) invest in the supplier's capabilities to improve SR; and (ii) disclose SR information to consumers. A third party may disclose the true level of SR, which can lead to a penalty for the manufacturer. Our results show that greater visibility helps the manufacturer to better tailor her investment. In addition, disclosing SR leads to an improvement in supplier SR practices, but this disclosure is least likely when the supplier has average (not too low and not too high) SR practices.

## 3 - Can Brands Claim Ignorance? Unauthorized Subcontracting in Apparel Supply Chains

Anna Saez de Tejada Cuenca, UCLA Anderson School of Management, 110 Westwood Plaza, B-501, Los Angeles, CA, 90095, United States, Felipe Caro, Leonard Lane

The collapse of the Rana Plaza building in Bangladesh brought into focus the poor safety conditions faced by many workers in the apparel industry. A common way in which safety and environmental standards are violated is through unauthorized subcontracting. We analyze empirically some factors that can lead suppliers to outsource their production to third parties without their retailers' knowledge. We use data provided by a supply chain manager that consists of over 30,000 orders, including 36% of subcontracted ones. Our results provide managerial insights to retailers on what factory and order characteristics increase the probability of unauthorized subcontracting, and how it can be prevented.



## ■ TE17

North Bldg 127C

**Joint Session MSOM/Practice Curated: New Frontiers in Operations Management**

Sponsored: Manufacturing &amp; Service Oper Mgmt/Supply Chain

Sponsored Session

Chair: Nitin Bakshi, University of Utah, Salt Lake City, UT, 84112-8939, United States

**1 - Mitigating Disruption Cascades in Decentralized Supply Networks**

Nitin Bakshi, University of Utah, 1655 East Campus Center Drive, Salt Lake City, UT, 84112-8939, United States, Shyam Mohan

Using a game-theoretic analysis, we study how firms in a decentralized supply network invest in mitigating the risk from disruption cascades. Specifically, we highlight the informational implications of the equilibrium investments

**2 - The Emergence of Superstar Firms: Endogenous Multi-market Competition**

Kostas Bimpikis, Stanford University, 655 Knight Way, Stanford, CA, 94305, United States, Sergio Camelo, Michael Koenig

We analyze competitive markets with multi-product firms competing in Cournot. We provide an equilibrium characterization in which both production levels and the market structure are endogenously determined. For homogeneous firms and convex production costs we show that the equilibrium market structure is such that each firm participates in only one market. In contrast, in the presence of economies of scale the resulting market structure takes the form of a nested graph. We recapitulate nestedness as a novel empirical fact in a unique panel dataset of firms. The policy implications are discussed with examples of deregulation affecting market entry, firm exit and mergers and acquisitions.

**3 - Designing Rewards-based Crowdfunding Campaigns for Strategic Backers**

Souptika Chakraborty, Duke University, Durham, NC, United States, Robert Swinney

We study a model of rewards-based crowdfunding with the all or nothing funding mechanism. The creator of a campaign solicits pledges from backers, and if total pledges exceed a pre-determined threshold, the campaign is successful, the creator receives all pledges and each backer receives a reward. Otherwise, the campaign fails and backers are refunded their pledges. We determine how a creator should design her campaign when the uncertainty of receiving the reward makes backers behave strategically.

## ■ TE18

North Bldg 128A

**Operations/ Marketing Interface III**

Contributed Session

Chair: Philippe Chevalier, UCL, Louvain School of Management - CORE, L1.03.01, Louvain La Neuve, B1348, Belgium

**1 - Service Investment for Online Retailers with Social Media**

Ruiqi Hou, University of Science and Technology of China, No.96 Jinzhai Street, Room 706, School of Management, USTC East Campus, Hefei, 230026, China

We investigate the impact of investments in customer service experience in a market with one or two major competing online retailers. The firms decide on investments aimed at improving the customer service experience. We distinguish two variants: one Nash case and a leader-follower (Stackelberg game) case. For both cases, the optimal investment cost, optimal profit per unit time, and the effect on market share are calculated. We show that the presence of a social network leads to faster convergence of the market, while it also impacts the profits and market share. Numerical analysis shows that both the leader and the follower invest more when a social network exists and higher profits are gained.

**2 - Creating Value from False-failure Returns**

Eylem Koca, Ozyegin University, Nisantasi Mah. Orman Sk. 34-36, Cekmekoy, Istanbul, 34794, Turkey

We study the problem of creating the most value out of false-failure returns (consumer returns with little to no verifiable defect). In a comprehensive two-period model incorporating product information, return policies, product generations and trade-in upgrades, we identify the optimal conditions for the seller to choose remanufacturing, open-box sales or salvaging, when faced with false-failure returns from strategic consumers. We also investigate the implications of consumer moral hazard and the implications on sustainability performance.

**3 - Channel Coordination Between Manufacturers and Competing Retailers with Fairness Concerns**

Rikuo Yoshihara, Keio University, Yokohama, Japan, Nobuo Matsubayashi

We consider a two-tier supply chain where a single manufacturer sells its product to consumers through two competing retailers, and investigate how fairness concerns, where all channel members have inequity aversion, may affect channel coordination. We show that when the retailers are moderately differentiated, all channel members' fairness concerns can achieve the profit distribution among the channel members that satisfies the maximum channel profitability, the maximum channel utility, and that increases their individual profits compared with the case without fairness concerns.

**4 - Encroachment and Process Investment with Spillovers**

Houcai SHEN, Nanjing University, Department of Management Science, and Engineering, Nanjing, 210093, China, Xia Jing

In this paper, we reveal that a retailer may benefit from supplier encroachment. We develop game theoretic models under different cases and then make two-party comparisons of the equilibrium outcomes. The results show that the supplier prefers encroachment, despite of whether he makes investment. Nevertheless, his investment policy depends critically on a threshold of investment efficiency. The retailer is better off when the two products are sufficiently differentiated and investment externality is strong enough.

**5 - Retail Competition at the E-commerce Age**

Qiang Li, Rutgers Business School-Newark and New Brunswick, New Brunswick, NJ, United States, Xiaowei Xu

We study retail markets, in which a brick-and-mortar retailer competes against an e-retailer. Many department stores announced to close more stores. On the other side of the competition, e-retailers have been growing their business at a double-digit annual rate. The brick-and-mortar retailer needs economies of scale to cover indirect costs, but the e-retailer is free from the scale constraint. We build a mathematical model and try to answer some questions such that: will online retailers win the final trophy and eliminate more local stores in the next decade? What's the suitable trade zone of a local store on certain population density?

**6 - Joint Optimization of Variable Pricing and Supply**

Philippe Chevalier, Professor, UCLouvain, Louvain School of Management - CORE, L1.03.01, Louvain La Neuve, B1348, Belgium, Alejandro Lamas

In most of the lot-sizing models, demand is considered as a parameter and in most pricing models the supply of goods is considered as a parameter. We develop new models and algorithms to jointly optimize supply and demand management combining lot sizing and variable pricing with strategic customers. In particular, we study the optimal scheduling of promotions to maximize profits taking into account revenues but also operations costs.

## ■ TE19

North Bldg 128B

**Inventory Ordering and Dynamic Assortment Decisions in Revenue Management**

Sponsored: Revenue Management &amp; Pricing

Sponsored Session

Chair: David Simchi-Levi

Co-Chair: Will Ma, Massachusetts Institute of Technology, Cambridge, MA, 02139, United States

**1 - Online Assortment Optimization with Reusable Resources**

Vineet Goyal, Columbia University, 304 S.W. Mudd Building, 500w 120th Street, New York, NY, 10027, United States, Garud N. Iyengar, Shuangyu Wang

We consider an online assortment optimization problem with  $n$  substitutable products with reusable capacities. In each period, a user with a preference model (potentially adversarially chosen) arrives to the platform, and is offered an assortment of products that have available capacity. The goal here is to compute a policy that maximizes the expected revenue of the platform over a finite horizon. We show that a simple myopic policy, that does not require any information about future arrivals or the distributions of usage time, is  $1/2$  optimal with respect to a clairvoyant optimal that has full information about the sequence of user types (or choice models) and the usage time distributions.

## 2 - Dynamic Assortment Optimization With Inventory Cost

Venus Lo, Cornell University, 206 Rhodes Hall, Cornell University, Ithaca, NY, 14853, United States, Huseyin Topaloglu

We consider a dynamic assortment optimization problem of selecting an assortment of products and their inventory level to offer to a stream of customers. Unlike traditional revenue management problem where the seller controls the products available to each arriving customer, the seller only makes initial inventory decisions. There is a cost of stocking the inventory, with no salvage value. The assortment available to each customer depends on the initial stock and the purchases of preceding customers, who are willing to substitute. We present a dynamic program for deterministic customer arrivals with nested preferences and develop related heuristics for the case of stochastic customer arrivals.

## 3 - Inventory Balancing With Online Learning

Xinshang Wang, Columbia University, New York, NY, United States, Wang Chi Cheung, Will Ma, David Simchi-Levi

We study an online resource allocation problem. A manager needs to allocate limited resources to a heterogeneous pool of customers arriving in real time, while maximizing a certain notion of cumulative reward. The manager can observe a list of feature values of each arriving customer, which allow the manager to learn personalized customer behavior and customize allocation decisions. The challenge is to allocate resources effectively, in the absence of any demand forecast model and under uncertain customer behavior. We propose online allocation algorithms with provably tight performance guarantee. Our technique combines online learning theories with competitive analysis.

## TE20

North Bldg 129A

### Using Pricing to Manage On-line Marketplaces

Sponsored: Revenue Management & Pricing

Sponsored Session

Chair: Robert L. Phillips, Uber, San Francisco, CA, 94101, United States

#### 1 - Surge Moves Drivers: Evidence From a Natural Experiment at Uber

Alice Lu, Uber, San Francisco, CA, United States, Peter Frazier, Oren Kislev

Ridesharing platforms use dynamic pricing (so-called “surge pricing”) to raise prices when demand from riders outstrips drivers’ availability. This is intended to reduce rider demand and attract drivers. While short-run price increases clearly influence riders, anecdotal evidence on whether they move drivers is mixed, with experienced drivers counselling against “chasing surge”. Using a natural experiment created by a surge pricing service outage affecting a portion of Uber’s driver-partners, we show that visibility of the surge heatmap increases drivers’ earnings, attracts drivers toward areas with higher surge prices, and explains 10%-60% of drivers’ self-positioning decisions.

#### 2 - An Empirical Analysis of Price Formation, Utilization, and Value Generation in Ride Sharing Services

Tunay Tunca, University of Maryland, 4361 Van Munching Hall, Robert H. Smith School of Business, College Park, MD, 20742, United States, Weiming Zhu, Liu Ming, Yi Xu

Using data obtained from a leading ride-sharing company, we construct and estimate a discrete choice based model of price, demand and supply formation in ride-sharing services based on operational characteristics such as driver utilization and demand intensity. Further, we conduct counterfactual analysis to examine efficiency and welfare implications of regulation and pricing strategies such as surge pricing.

## TE21

North Bldg 129B

### Joint Session RMP/MSOM: Topics in Revenue Management and Learning

Sponsored: Revenue Management & Pricing

Sponsored Session

Chair: Arnoud den Boer, University of Amsterdam, Amsterdam, Netherlands.

#### 1 - Believing in Analytics: Managers’ Adherence to Price Recommendations From a Decision Support System

Anna Saez de Tejada Cuenca, PhD Student, UCLA Anderson School of Management, Los Angeles, CA, United States, Felipe Caro

We analyze empirically the drivers of adherence to the prices recommended by a decision support system during the sales season of a fast fashion retailer. We study the effect of two interventions aimed to increase adherence, as well as the drivers

of the evolution of adherence over time. One of the firm’s interventions, a change in the way revenue was displayed in the DSS’s interface, increased adherence to its price recommendations. Moreover, managers’ systematic deviations from the DSS’s recommendations are compatible with well-known behavioral biases such as loss aversion and salience of the inventory. Our results provide insights on how to design better DSSs to entice practitioners to use them.

#### 2 - Assortment Rotation and the Value of Concealment

Kris Johnson Ferreira, Harvard Business School, Morgan Hall 492, Boston, MA, 02163, United States, Joel Goh

We study one reason why frequent assortment rotations can be valuable. Namely, by distributing its seasonal catalog of products over many assortments, the retailer conceals a portion of its product catalog from consumers, injecting uncertainty into the consumer’s relative product valuations. Rationally acting consumers may respond to this uncertainty by purchasing more products, generating additional sales for the retailer. We refer to this phenomenon as the value of concealment. We develop a consumer choice model and stochastic dynamic program to study the value of concealment.

#### 3 - Non-stationary Stochastic Optimization with Applications to Dynamic Pricing

Yining Wang, Carnegie Mellon University, 5000 Forbes Avenue, 8203 Gates-Hillman Center, Pittsburgh, PA, 15213, United States, Xi Chen, Yuxiang Wang

We consider a non-stationary sequential stochastic optimization problem, in which the underlying cost functions change over time under a variation budget constraint. We propose an  $\$L_{[p,q]}$ -variation functional to quantify the change, which yields less variation for dynamic function sequences whose changes are constrained to short time periods or small subsets of input domain. Under the  $\$L_{[p,q]}$ -variation constraint, we derive both upper and matching lower regret bounds for smooth and strongly convex function sequences, which generalize previous results in Besbes et. al. (15). Our results reveal some surprising phenomena such as the curse of dimensionality of the function domain.

#### 4 - Price Optimization under The Finite-mixture Logit Model

Arnoud V. den Boer, University of Amsterdam, Science Park 107, Amsterdam, Netherlands, Ruben van de Geer

We present a price optimization algorithm under the finite-mixture logit model, a choice model that can capture customer heterogeneity. Our algorithm has theoretical performance guarantees and desirable computational properties.

## TE22

North Bldg 130

### Application of Revenue Management and Pricing: Interaction of Supply and Demand

Sponsored: Revenue Management & Pricing

Sponsored Session

Chair: Shadi Sharif Azadeh

#### 1 - Robust Demand Estimation under the Multinomial Logit Model Using Sales Transaction Data

Sanghoon Cho, University of South Carolina, Columbia, SC, United States, Jongho Im, Pelin Pekgun, Mark Ferguson

We propose a statistical procedure that can estimate the effect of product attributes and unobservable lost sales under a choice-based demand model using only historical sales transactions, product availability data, and market share information. Our proposed approach does not require time-homogeneous arrival rates, and allows for varying product attributes and choice sets over time. A set of simulation studies and an application to a real hotel dataset are conducted in comparison to several existing methods.

#### 2 - A Revenue Management Model for on Demand Systems

Yousef Maknoon, Delft University of Technology, Delft, Netherlands, Bilge Atasoy, Moshe E. Ben-Akiva, Michel Bierlaire, Shadi Sharif Azadeh

This paper presents a revenue management model for mobility on-demand systems. When a customer arrives to the system, the model decides about the mixture of products offered to the customer to maximize the expected revenue. The expected revenue from an offer set is defined by the price and the demand of each offered product. We formulate the problem as a mixed-integer linear model and present a branch and bound algorithm to solve it. Computational results depict the performance of our approach.

### 3 - Choosing Fairly with Unknown Metric Preferences

Anilesh Krishnaswamy, Stanford University, Stanford, CA, 94305, United States, Ashish Goel, Kamesh Munagala

We consider the problem of choosing a single alternative based on the ordinal preferences of agents on a set of alternatives, under the assumption that the preferences of agents are derived from an underlying unknown metric space. This model is motivated in part by specific settings such as facility location (e.g. choosing locations for schools/hospitals) and in general by preference aggregation in large feature spaces. We identify algorithms that provably choose alternatives that are close to optimal simultaneously for a wide class of convex objective functions which includes various fairness measures such as social welfare (SUM), Nash welfare (PRODUCT) and Rawlsian welfare (MAX).

## ■ TE23

North Bldg 131A

### Recent Advance in Healthcare Management

Sponsored: Manufacturing & Service Oper Mgmt/Healthcare Operations

Sponsored Session

Chair: Nan Liu, Boston College, Chestnut Hill, MA, 02467, United States

Co-Chair: Pengyi Shi, Purdue University, Purdue University, West Lafayette, IN, 47907, United States

#### 1 - Risk-sharing Agreements for New Medical Treatments

Ozge Yapar, University of Pennsylvania, Wharton School of Business, 3730 Walnut Street, Philadelphia, PA, 19103, United States, Stephen E. Chick, Noah Gans

Any estimate of a new medical treatment's value that relies on clinical-trial data can have significant residual uncertainty. So-called post-marketing data, captured after the treatment has entered the market and is used by the general population, can augment clinical-trial data to better validate its safety, efficacy, and economic value. To better manage the risks associated with this post-trial residual uncertainty, new price updating mechanisms are under consideration around the world. We analyze these new risk-sharing arrangements.

#### 2 - Supply Disruptions in Sterile Injectable Drug Supply Chain

Parshuram Sambhajirao Hotkar, UT Austin, Austin, TX, 78751, United States, Diwakar Gupta

Injectable drug shortages are a serious problem in the US. Reasons for such shortages vary including contamination and facility updates. We consider a setting in which two firms sell a perfectly a substitutable drug in the same market. Firms make capacity decisions first, followed by production decisions. Firm 1 is subject to production shut downs, but Firm 2 is not. Both firms choose capacities before observing supply disruption, based on the likelihood and intensity of the supply shock. Our analysis focuses on how a central planner should distribute incentives to improve disruptions - either to the safer firm, or to the riskier firm, or to both, and if both, then in what combination.

#### 3 - A New Value Proposition for Reducing Readmissions: Dynamic Staffing for Post-discharge Follow-ups

Alex Mills, Indiana University Bloomington, 1309 E. Tenth St, Bloomington, IN, 47405, United States, Jonathan Helm, Shanshan Hu, Xiaoyang Yu, Jivan Romain Deglise-Hawkinson, Julian Pan

Under a simple staffing policy, the cost of providing follow-ups for discharged patients may outweigh the benefit of reduced hospital readmissions. Motivated by the current state of practice, we formulate a capacity planning problem with a rolling horizon that balances the time-nonhomogeneous benefit of readmission reduction against the cost of providing capacity and the potential cost of wasted capacity, since hospital discharges are stochastic. Unlike when using a simple Newsvendor heuristic, following up with a larger population of patients is cost-effective when capacity is planned using our method.

#### 4 - Managing Outpatient Care Services Under Strategic Walk-in Patients

Nan Liu, Boston College, 140 Commonwealth Avenue, Fulton Hall, Room 340, Chestnut Hill, MA, 02467, United States, Shan Wang, Willem van Jaarsveld, Guanlian Xiao

Outpatient care providers often accept both scheduled patients and walk-in patients without appointments. Patients may choose to book an appointment or to walk in directly, depending on their health condition and the utility of each option. In this talk, we discuss how an outpatient care provider should manage her capacity taking into account such strategic behavior of patients.

## ■ TE24

North Bldg 131B

### E-Business/Commerce & Accounting

Contributed Session

Chair: Shaoqin Ye, Xiamen University, 422 Siming South Road, Xiamen, 361005, China

#### 1 - How Much to Share. A Study to Understand the Interplay Between Firms and Their Affiliates

Siddharth Bhattacharya, PhD Student, Fox School of Business, Temple University, Alter Hall, 1801 Liacouras Walk, Philadelphia, PA, 19122, United States, Subodha Kumar, Sunil Wattal

Firms increasingly utilize third party affiliates to advertise on their behalf. The focus of our research is to find what optimal pricing and advertising strategies between firms and affiliates maximize profits and how does product quality, customer heterogeneity, affiliate type and type of ad contract (with Google) affect those strategies.

#### 2 - Optimal Pricing Decisions for an Omni-channel Retailer

Nevin Mutlu, Eindhoven University of Technology, P.O. Box 513, Eindhoven, 5600 MB, Netherlands

In this research, we develop an analytical model to study a dual-channel retailer's pricing policy across store and online channels, considering that different channels exhibit different cost structures, yet an inconsistent pricing scheme across channels may lead to lower sales due to consumer confusion.

#### 3 - Optimizing NFL Player's Contracts

Wei Chen, Assistant Professor, York College of Pennsylvania, 211 Willman Business Center, 441 Country Club Road, York, PA, 17403, United States, Benjamin V. Neve

National Football League (NFL) implements restrict salary cap for all professional teams, therefore successfully investing in players' contracts is a key factor to keep a team maintaining competitive. By referring past 30 years NFL players' statistics, this research develops a weighted optimization model to offer recommendations on any free agent player's contract based the player previous performance as well as other similar players' historical performance. A real NFL case has been used to test the model, it shows the developed model offers a better solution than current management system.

#### 4 - Influence of Controlling Shareholders' Pledge on the Quality of Earnings: A Research Based on A-share Listed Companies in China

Shaoqin Ye, Professor, Xiamen University, 422 Siming South Road, Xiamen, 361005, China, Danxia Guo

This study explores the impact of equity pledges by controlling shareholders of listed companies on the quality of earnings using Chinese A-share listed companies during 2007-2016 as a sample. The empirical findings indicate that, other things being equal, the companies whose controlling shareholders have pledged their stocks have a higher quality of earnings than those whose controlling shareholders have no equity pledge. In addition, such an effect is negatively moderated by the degree of marketization.

## ■ TE25

North Bldg 131C

### Joint Session Service Science/Practice Curated: Analytics in Higher Education and Science Workforce

Sponsored: Service Science

Sponsored Session

Chair: Maryam Alsadat Andalib, Virginia Institute of Technology, Blacksburg, VA, 24060, United States

#### 1 - Happy With a Baby and a Declined Tenure: Effects of Tenure-clock Extension Policies on Career Outcomes of New Parent Faculty Members

Maryam Alsadat Andalib, Data Scientist, Ford Motor Company, Dearborn, MI, United States, Navid Ghaffarzadegan

In this paper, we look at the support mechanisms for new-parent, tenure-track faculty in universities with a specific focus on tenure-clock extension policies. We construct a unique data set to answer questions around the effectiveness of removing the stigma connected with automatic tenure-clock policies. Our results show that such policies are successful in removing the stigma and that, overall, faculty members that have newborns and are employed by universities that adopt auto-TCE policies stay one year longer in their positions than other faculty members. In addition, we investigate the effect of auto-TCE policies on other career outcomes (e.g., getting tenure and job satisfaction).



## 2 - Using Simulation Modeling to Examine Policy Effects on the Workforce Outcomes of Women in Academic Science

Julie A. Maurer, Lead Research Manager, The Ohio State University, Columbus, OH, 43210, United States

Despite gains made over the past 20 years toward gender pay equity for female scientists working in academic research in the U.S., a persistent gap suggests that existing policies have not gone far enough. Insights into how the workforce structure, institutional policies and employer preferences interact to impact the career development of female scientists using ABM and SD modeling will be shared.

## TE26

North Bldg 132A

### Information in Queueing Systems

Sponsored: Service Science

Sponsored Session

Chair: Ricky Roet-Green, Simon Business School, University of Rochester, Rochester, NY, 14627, United States

#### 1 - The Benefit and Cost of Skipping the Line

Yang Li, Chinese University of Hong Kong, 12 Chak Cheung Street, Cheng Yu Tung Building, Hong Kong, Opher Baron, Xiaole Chen

If you do not have time to wait in a long line to get your morning caffeine fix or to grab your lunch, now you can skip the line and order online. Thanks to the advancing IT technology, more and more restaurants, e.g., Starbucks and McDonald's, are offering online ordering without customer physical presence in the service line. We study the impacts of this novel business model with both online and in-store customers waiting to be served. We find that although the provider enjoys a revenue increase, both online and in-store customers endure longer delays and the social welfare may suffer.

#### 2 - Efficient Inaccuracy: User-generated Information Sharing in a Queue

Jianfu Wang, Nanyang Business School, Nanyang Technological University, Block S3-B2C-85, 50 Nanyang Avenue, Singapore, 639798, Singapore, Ming Hu

We study a service system which does not have the capability of monitoring and disclosing its real-time congestion level. However, the customers can observe and post their observations online, and future arrivals can take into account such shared information when deciding whether to go to the facility. We compare the user-generated information structure, which requires no costly investment, with full and no information structures. Perhaps surprisingly, we show that shared information always generates higher social welfare than no information and than full information when the offered load is high or the service is very popular.

#### 3 - The Armchair Decision: To Travel to a Queue or Not

Ricky Roet-Green, Simon Business School, University of Rochester, C3-345 Carol Simon Hall, Rochester, NY, 14627, United States, Refael Hassin

The availability of queue-length online information affects the way we model service systems. Models which assume customers have full information about the queue length (i.e., observable queues), also assume that if the customer decides to join the queue, joining is instantaneous. But in real-life settings, it is more natural to assume that customers who learn about the service current queue length have to travel to the service, and while they are on their way, the queue length may change: customers may complete their service and leave, others may arrive and join the queue. Our paper investigates the question how does information affects customers' decision to travel to the queue.

## TE27

North Bldg 132B

### Mass Customization and Applications

Sponsored: Manufacturing & Service Oper Mgmt/Supply Chain

Sponsored Session

Chair: Ali Fattahi, University of California-Los Angeles, Los Angeles, CA, 90095, United States

Co-Chair: Reza Ahmadi

#### 1 - Supply Chain Geography and Product Quality

Robert Louis Bray, Kellogg School of Management, Northwestern University, 830 Hinman Ave., 2s, Evanston, IL, 60202, United States

We study the effect of supply chain proximity on product quality by merging four independent data sources from the automotive industry. We estimate that increasing the distance between an upstream component factory and a downstream plant by an order of magnitude increases the component's expected

defect rate by 3.9%.

#### 2 - Procurement Contracting Under Product Recall Risk

Lauren Xiaoyuan Lu, University of North Carolina at Chapel Hill - Kenan Flagler, Kenan-Flagler Business School, CB #3490, McColl Building 4701, Chapel Hill, NC, 27599, United States, Jayashankar M. Swaminathan, Yue Zhang, Gang Wang

We consider a model in which a manufacturer outsources to a supplier the production of a component, which is subject to potential quality failure leading to a product recall. The manufacturer acts as the Stackelberg leader offering a recall cost sharing contract to the supplier. We analyze two settings: a pull system in which the supplier makes the quantity decision and a push system in which the manufacturer makes the quantity decision. We find that the manufacturer achieves a higher production quantity and induces a higher quality effort of the supplier in the push system than in the pull system.

#### 3 - Mass Customization and the Parts Capacity Planning Problem

Ali Fattahi, University of California-Los Angeles, Anderson School of Management, B501, Los Angeles, CA, 90095, United States, Sriram Dasu, Reza Ahmadi

We study a new parts capacity planning problem motivated by a global auto manufacturer that offers 100-500 car options. The set of end-products (producible configurations) is in the order of 1025-1040. Since it is impossible to forecast the demand for producible configurations, firms forecast demand for options. Parts' requirement cannot be directly determined based on options' forecast since a large number of parts' requirements (up to 60%) is based on the combinations of options selected. The problem of determining parts' requirement is a large-scale NP-Hard problem. We develop an effective approach for solving large industrial instances and compare our approach to that of the current practice.

## TE28

North Bldg 221A

### Logistics

Contributed Session

Chair: Yulan Bai, SMU, Dallas TX, 75205, United States

#### 1 - A New Methodology Combining JIT with Group Technology to Optimize Order Fulfillment Process for Online Supermarket

Minfang Huang, North China Electric Power University, 2 Beinong Road, Beijing, 102206, China, Yanxin Wang, Xiangpei Hu

Aiming at the difficulty of order processing in multi-variety, small-batch, cross-warehousing and consolidation of online supermarkets, a pull order processing model combining JIT and group technology was proposed. We use the similarity principle of the group technology to establish the flow process path and refer to the free type assembly line to set the takt time for batch orders, in which the order item is pulled to the right position at right time. The model achieves the goal of the shortest time for order processing by reducing the idle time of picking, sorting, and packaging and the waiting time of the order items in buffers.

#### 2 - Sequencing Triple-spreader Crane Operations: Mathematical Formulation and Heuristic Algorithm

Shabnam Lashkari, PhD Candidate, University of Wisconsin-Milwaukee, Milwaukee, WI, 53202, United States, Matthew Petering, Yong Wu

This paper investigates the problem of scheduling a triple-spreader (i.e. tandem lift) crane when lifts are subject to a weight limit. We formulate the problem as an integer linear program and develop a fast method for computing a lower bound on the optimal objective value. In addition, we devise a genetic algorithm that produces high quality solutions for small, medium, large, and very large problem instances.

#### 3 - An Exact Algorithm for an Assembly Routing Problem

Masoud Chitsaz, CIRRELT, Pavillon Andre-Aisenstadt, 2920 chemin de la Tour, Montreal, QC, H3T 1J4, Canada, Jean-François Cordeau, Raf Jans

We consider an integrated planning problem that combines production, inventory and inbound transportation decisions. We provide a mixed integer programming formulation of the problem and propose several types of valid inequalities to strengthen the linear programming relaxation. We propose new algorithms to separate the subtour elimination constraints with fractional node visits. The inequalities and separation procedures are used in a branch-and-cut algorithm. Computational experiments on a large test bed show the performance of the valid inequalities as well as the separation procedures.

#### 4 - The Facility Location Problem with Joint Disruptions

Vishwakant Malladi, Graduate Student, University of Texas-Austin, McCombs School of Business, CBA 5.202, IROM, Austin, TX, 78712, United States, Kumar Muthuraman

Classical facility location problems do not incorporate the possibility of correlated disruptions among facilities. Existent Literature focuses on simplistic disruption probabilities. We propose using Subordinated Markov chains to model the probability of the correlated risk of disruptions. Parameterizing the disruption probabilities offers more realistic and easy-to-simulate disruption distributions while using fewer parameters. We also propose algorithms that calibrate the Subordinated Markov Chain model and optimize for the facility location choices under correlated disruptions.

#### 5 - Backhaul Profit Maximization

Yulan Bai, Doctoral Student, Southern Methodist University, Dallas, TX, United States, Eli Olinick

We present a MIP for the backhaul profit maximization problem in which a freight carrier seeks to generate revenue from an empty delivery vehicle's backhaul trip from its last scheduled delivery to its depot by allowing it to deviate from the least expensive (or fastest) route to accept delivery requests between intermediate points as allowed by its capacity and required return time. The MIP is inspired by a novel representation of multicommodity flow that significantly reduces the size of the constraint matrix, LP upper bound on optimal profit, and solution time compared to a formulation based on the classical node-arc representation.

### ■ TE29

North Bldg 221B

#### Modeling Dynamic Transportation Networks in the Era of Connectivity, Automation, and Sharing

Sponsored: TSL/Urban Transportation

Sponsored Session

Chair: Rui Ma, University of California, Davis, CA, 95618, United States

Co-Chair: Xuegang Ban, University of Washington, Seattle, WA, United States

#### 1 - Modeling Dynamic User Equilibrium Using Dynamic Complementarity Systems

Rui Ma, University of California, Davis, Davis, CA, United States, Xuegang Ban

We present a mathematical framework, called differential complementarity systems (DCS), to model and solve link-node continuous-time dynamic user equilibrium. We also discuss possible ways to extend the DCS formulations to model emerging mobility services in transportation.

#### 2 - Ridesharing on a Many-to-one Network with Multiple Corridors and a Common Destination

Rui Ma, University of California, Davis, Davis, CA, 95616, United States, Michael Zhang

We study the ridesharing morning commute traffic in a many-to-one network with a common parking area. The morning commute equilibrium problem of both ridesharing role and departure time choices in a many-to-one network is formulated and analyzed. The common parking area and its common parking disutility are shared by travelers on multiple corridors, each of which is represented by a single bottleneck link. It is found that the common parking disutility connects choice behavior and traffic flow patterns on all corridors, so that the problem is significantly different from the morning commute problems with only a single bottleneck link regardless the presence of ridesharing travel modes.

#### 3 - A Data-driven Car-truck Dynamic Traffic Assignment Model

Zhen Qian, Carnegie Mellon University, 5000 Forbes Avenue, Pittsburgh, PA, 15213, United States, Xidong Pi, Wei Ma

Traffic simulation with heterogeneous traffic flow is central to traffic management, for example when examining the impact of new demand/restriction of emerging vehicles. In real-world traffic flow, cars and trucks have different attributes, hence evolve in different behaviors. In this research, we built and implemented a realistic and applicable mesoscopic car-truck traffic simulation model that are data friendly for dynamic traffic assignment, with separate demand estimation and route choices for cars and trucks. It performs well in traffic impact analysis of development projects in case studies.

### ■ TE30

North Bldg 221C

#### Practice- Smart City and Urban Planning I

Contributed Session

Chair: William Knudson, Clemson University, Clemson, SC, 29634, United States

#### 1 - Spatio-temporal Flexible Parking System

Xin Wang, University of Wisconsin-Madison, Madison, WI, United States, Xiaotian Wang

In a reservation-based parking system, customers departing late cause service failure for subsequent customers. To guarantee the service level, the parking system needs to run at a low utilization, which is a huge waste of parking resources, especially in congested urban area. From the perspective of the public regulator, we propose a flexible reservation system with spatial-temporal flexibility to address above issues and manage social surplus. A game-theoretical model is used to capture the customers' utility over the flexibility.

#### 2 - Site Characterization by Dem And Satellite Images to Estimate Subsurface Site Conditions

Young-Ji Byon, Associate Professor, Khalifa University, Al Saada Street and Airport Road, P.O. Box 127788, Abu Dhabi, 127788, United Arab Emirates, Tadahiro Kishida, Rita Sousa

Site information need to be obtained for civil infrastructure construction before actual field survey is performed. Digital elevation models (DEM) have been successfully applied for this purpose to estimate the subsurface site conditions. Satellite images are also sometimes used to characterize site conditions visually based on the practitioners' experience. However, the combination of the data from DEM and satellite images have not been explored to estimate the subsurface site conditions. This study investigates the methodology to estimate the averaged subsurface site conditions for Japan from DEM and satellite images which are public available for the entire world.

#### 3 - Quality of Service Constrained Microgrid Optimal Scheduling

Yiwei Wu, University of Houston, 4800 Calhoun Road, Houston, TX, 77004, United States, Gino J. Lim, Masoud Barati

The microgrid (MG) optimal scheduling ensures the economic operation subject to secure performance. To maintain the MG stability, MG should have enough reserve capacity. We define a Quality of Service (QoS) index to evaluate the effects of managing the scheduling uncertainties. Under particular QoS, the MG uses estimated reserve quantity to schedule its operation. A two-stage mixed-integer stochastic programming model is proposed to solve microgrid scheduling problem, in which the first stage is to schedule a microgrid under a normal operating condition, and the second stage is to adjust the first stage decision by finding the optimal provided reserve of microgrid under operation uncertainties.

#### 4 - Urban Climate and Air Quality Services for Climate Change Planning – Europe Case Studies

Roberto San Jose, Professor, Tech. University Madrid, UPM Campus Montegancedo, Boadilla del Monte, Madrid, Spain, Juan Luis Perez-Camano, Libia Perez, Rosa Maria Gonzalez-Barras

UPM has developed integrated urban climate and air quality services to cover the special needs of city planners to develop climate change mitigation strategies. The results are based on high resolution numerical simulations run on high performance computers platforms. The methodology includes health impact assessments to know how climate change may affect the health of citizens.

#### 5 - Using Bike Route Data Visualization to Inform Bicycle Share System Design and Redesign

William Knudson, Clemson University, Clemson, SC, United States, Mary Beth Kurz, Paul Glenn, Jack Henderson, Ciara Hill, Anderson Kemp, Isabella Kazmier

Small entities, such as small universities or towns, may want, for reasons such as sustainability or livability, want to invest in a bicycle sharing system with a limited budget, and not be able to follow best-practices in designing their systems. Using crowd-sourced data, such as that collected by Strava users, planners may be able to determine reasonable station location and potential bike routes. In this study, we utilize longitude, latitude and elevation data collected from bicyclists traveling through and on Clemson University's campus, as well as pilot bike share system usage data, to provide updates to the system design.

## ■ TE31

North Bldg 222A

### TSL Best Paper Session

Sponsored: Transportation Science & Logistics

Sponsored Session

Chair: Tom Van Woensel, Eindhoven University of Technology, Industrial Engineering, Den Dolech 2, Pav F08, Mb Eindhoven, NL5600, Netherlands

#### 1 - TSL Best Paper Award

Tom Van Woensel, Eindhoven University of Technology, Industrial Engineering, Den Dolech 2, Pav F08, Mb Eindhoven, NL5600, Netherlands

The TSL Best Paper Award is given every year to an outstanding paper in the field of transportation science and logistics. The paper must have been published in a refereed journal and must present innovative approaches for solving complex problems in transportation and/or logistics, with an emphasis on operations research and quantitative methods.

## ■ TE32

North Bldg 222B

### Practice - Reverse Logistics/ Manufacturing I

Contributed Session

Chair: Debdatta Sinha Roy, Robert H. Smith School of Business, University of Maryland, College Park, MD, 20742, United States

#### 1 - Evaluating Profitability of Remanufacturing Operations

Akshay Mutha, University of Vermont, Grossman School of Business, 55 Colchester Avenue, Burlington, VT, 05405, United States, Saurabh Bansal, V. Daniel R. Guide

We compare different methods for evaluating profitability of remanufacturing operations. We show the application of our model to current industry practices.

#### 2 - Modelling Price Dynamics for New and Remanufactured Smartphones

Supanan Phantratanamongkol, University of Birmingham, Birmingham, United Kingdom, Gu Pang

In this presentation, we model price dynamics of new and remanufactured smartphones listed on eBay by using functional data analysis. More specifically, we explore how price velocity and acceleration evolve over product life cycles. We further investigate how the impact of different factors on the price dynamics may vary. Our results shed light on the price dynamics of buy-it-now live listings and their price determinants guiding both eBay sellers and buyers in making informed decisions.

#### 3 - Optimization Models to Enable Job Rotation Schemes for Worker Safety

Amir Mehdizadeh, Auburn University, Auburn, AL, United States, Alexander Vinel, Mark Schall, Richard Seseek, Sean Gallagher

We consider the problem of employing job rotation schemes to improve worker safety in a manufacturing setting by combining optimization methods with novel modeling techniques developed in the occupational safety community. The work is based on a recently proposed fatigue-failure model for musculoskeletal disorders (MSD) risk evaluation. This leads to nontrivial nonlinear and nonconvex optimization problems which we solve through a combination of analytical and numeric tools. We conduct a realistic case study and conclude that while in some cases job rotation can lead to improvements, its effect is highly dependent on the composition of the job pool.

#### 4 - A Stochastic Multi-echelon Multi-channel Network Problem

Yuan Wang, National University of Singapore, Singapore, 119260, Singapore, 119260, Singapore, Loo Hay Lee, Ek Peng Chew

To effectively plan supply chain operations, it is meaningful to integrate strategic decisions on manufacturing capacity with short-term production and distribution decisions considering both demand and supply uncertainties. However, research on integrated supply chain network planning is rather limited in the literature. In this research, a stochastic multi-echelon multi-channel network model is proposed to solve the real supply chain network planning problem with consideration of uncertain demand forecast, production yield and raw material procurement simultaneously. The objective is to minimize overall operating cost through an extended planning horizon.

#### 5 - Voting Mechanism Design in Randomized Strategic Social Choice

Debdatta Sinha Roy, Robert H. Smith School of Business, University of Maryland, College Park, MD, 20742, United States, Debasis Mishra

Consider a voting setup where each agent has an ordering over a set of alternatives. A randomized social choice function (RSCF) assigns probability distributions over the set of alternatives based on the orderings. A voting

mechanism should satisfy some socially acceptable properties, for example, unanimity and strategy-proofness. It is well known that an RSCF is unanimous and strategy-proof if and only if it is a random dictatorship. This leads to a roadblock for designing socially acceptable and truthful voting mechanisms. We construct a normalized scoring-based rule that is unanimous and weakly strategy-proof and, therefore, it is not dictatorial. It is fast to compute and easy to implement.

## ■ TE34

North Bldg 223

### 4:35 - 5:20 Responsive Learning Technologies/ 5:20 - 6:05 Lumina Decision Systems

Emerging Topic: Technology Tutorials

Emerging Topic Session

#### 1 - Online Games to Teach Operations and Supply Chain Management

Samuel C. Wood, Responsive Learning Technologies, 4546 El Camino Real, #243, Los Altos, CA, 94022, United States

Littlefield Technologies, the Supply Chain Game, and the Sourcing Game are online competitive assignments used to teach topics including process analysis, inventory control, supply chain management, and sourcing and purchasing. We will describe the games' learning objectives, typical assignments, and actual game results.

#### 2 - How to Engage with Your Clients for More Effective Analytics

Max Henrion, Lumina Decision Systems, Inc, Campbell, CA, United States

In this workshop, Max Henrion will show how you can use Analytica as a key aid for more effective conversations with your clients, including how to: Draw influence diagrams to help clients articulate their real objectives and decisions, and to work with them to frame and scope problems. Use sensitivity analysis to help your clients understand what data and assumptions really matter and why. Employ agile modeling methods to build decision tools that end users find usable and useful. Design compelling visualizations to provide your clients a basis for informed and confident decisions. Practicing analysts and modelers will find these methods effective for improving client engagement in conjunction with almost any analytics software, but Analytica is unique in offering features designed specifically to support this approach to interactive modeling. Active participants will receive a free 12-month Analytica license. If you already have Analytica, you can give it to a colleague.

## ■ TE35

North Bldg 224A

### Airline Competition and Coordination

Sponsored: Aviation Applications

Sponsored Session

Chair: Reed Harder, Dartmouth, Hanover, NH, 03755, United States

#### 1 - Machine Learning, Discrete Games, and Predictive Models of Entry in the Airline Industry

Kang Hua Cao, Hong Kong Baptist University, WLB 517, 34 Renfrew Road, Kowloon Tong, Hong Kong, Lei Kang, Chia-Mei Liu, Vikrant Vaze

In this paper, we intend to widen connections, and develop further relationships, between machine learning and economic theory. Existing forecasting methods use the reduced-form approach and maintain the so-called fixed network assumption. Ignoring the strategic effects in forecasting can lead to biased results. We implement supervised machine learning methods to infer the general form of the best response functions and the conditional choice probabilities of the game. Then, we apply the model and methods developed to the U.S. airline industry, to predict the probabilities involved in an airline company entering or exiting a market.

#### 2 - Game-theoretic Analysis of Reallocation Mechanisms of Airport Landing Slots

Jackie W. Baek, MIT, 77 Massachusetts Ave, Bldg E40-103, Cambridge, MA, 02139, United States, Hamsa Balakrishnan

We study reallocation mechanisms in which airlines can exchange landing slots amongst each other in the context of ground delay programs. Such mechanisms should not only be able to increase system efficiency, but they should also satisfy other desirable properties such as incentive compatibility and fairness. We analyze two reallocation mechanisms using a game-theoretic framework, and we develop simple, non-truthful strategies that airlines may use in these mechanisms. We show that the overall performance of the mechanisms can vary widely when gaming is introduced, and that enforcing fairness can have a large impact on the airlines' best strategies.



### 3 - Airline Passenger Route Share Forecast

Xufang Zheng, Iowa State University, 537 Bissell Road #2362,  
Ames, IA, 50010, United States, Chia-Mei Liu, Peng Wei

Airline passenger route share(directShare) is the ratio of direct passengers to total passengers on O&D level. It is an important feature of passenger flow distribution. DirectShare is an O&D specific feature, which is highly correlated with quarterly lag. Various supervised learning methods are carefully explored. The best model is gradient boosting machine(GBM), which has better prediction performance than FAA TAF-M directShare forecast model. Category based learning is newly proposed, which provides better prediction performance than GBM. The C-basedapTC model is the best category based learning model, which can provide a long term directShare forecast with less fluctuations.

### 4 - Game Theoretic Modeling for Airline Frequency Competition in Large Networks

Reed Harder, Dartmouth, 14 Engineering Drive, Hanover, NH,  
03755, United States, Vikrant Vaze

Airlines set daily flight frequencies on origin-destination segments across their networks. These decisions are made in competition with other airlines and in coordination with potential connecting flights on other segments, and have significant implications for the efficient functioning of the air transportation system. Game theoretic models have been used to analyze incentives in airline resource allocation, but often suffer from limited computational tractability and predictive accuracy in large networks with many connections. We present approaches for tractable game theoretic modeling in these large networks using approximate methods.

### 5 - Strategic Behaviors in Airport Capacity Allocation Mechanisms

Weilong Wang, Purdue University, West Lafayette, IN,  
United States, Alexandre Jacquillat, Vikrant Vaze

We develop an original bi-level game-theoretic approach to identify opportunities for strategic behaviors by non-atomistic users (e.g. airlines) in non-monetary mechanisms for infrastructure (e.g. airport) capacity allocation. We show that gaming opportunities are limited under a primary mechanism, where capacity is allocated to individual flights. In contrast, airlines may have strong gaming opportunities in a secondary mechanism, where capacity is allocated to airlines who may then swap their own flights. We present computational results comparing the overall performance of both mechanisms.

## TE36

North Bldg 224B

### Route Optimization for Drones

Emerging Topic: Robotics, Drones and Autonomous Vehicles in Logistics

Emerging Topic Session

Chair: Andrea Leticia Arias, Texas Tech University, Lubbock, TX, 79424, United States

#### 1 - A Heuristic Approach to Path-planning for Delivery Drones in Anisotropic Medium

Abhishake Kundu, Texas Tech University, 201 Indiana Avenue,  
# D210, Lubbock, TX, 79415, United States, Timothy Matis

The purpose of this research is to consider an efficient heuristic to navigate parcel delivery drones (in conjunction with trucks) in direction dependent uniform wind-fields. Constraints on specific relative velocities and available battery power for the drones makes this an excellent utilitarian extension on developing literature.

#### 2 - Route Optimization of Unmanned Area Vehicle with Radio Frequency Identification Interrogator

Victoria Carson, California State Polytechnic University, Dept of  
Industrial & Manufacturing Eng, San Luis Obispo, CA, 93407,  
United States, Tali Freed, Neil Wolfe, Jonathon Scott

The Close Enough Traveling Salesman model is used to optimize the route of an unmanned aerial vehicle (UAV) equipped with a radio frequency identification (RFID) interrogator. The UAV's mission is to identify assets located in a given area within the flight time of a single battery charge. Reported use cases include cattle in grazing pastures and oil drilling equipment.

#### 3 - A Deterministic Two-level Integrated Inventory Approach for Inventory Management at a Drone Battery Swap Station

Olivier Kwizera, University of Arkansas, Fayetteville, AR,  
United States, Sarah G. Nurre

We consider the problem of optimizing the management of batteries at a drone battery swap station which allows for instantaneous swapping of depleted batteries for fully-charged ones. Since drones are powered by batteries with limited flight range, the decisions made with regards to battery charging and replacement actions determine which geographically diverse locations are able to be serviced and when. We use a deterministic two-level integrated inventory model where the first and second inventory levels are battery charge and capacity, respectively. We develop a heuristic that minimizes average weighted delivery time and perform tests to deduce policy insights.

## TE37

North Bldg 225A

### Joint Session APS/Opt-Uncert: Interfaces between Applied Probability and Robust Dynamic Optimization

Sponsored: Applied Probability

Sponsored Session

Chair: Chaithanya Bandi, 1987, Evanston, IL, 60208, United States

#### 1 - Optimal Approximations for Two-stage Adjustable Robust Optimization Under Budgeted Uncertainty

Omar El Housni, Columbia University, New York, NY, 10027,  
United States, Vineet Goyal

We study the performance of affine policies for two-stage adjustable robust optimization problem under a budget of uncertainty set. The two-stage adjustable robust optimization problem is hard to approximate within a factor better than  $\Omega(\frac{\log n}{\log \log n})$  for budget of uncertainty sets where  $n$  is the number of decision variables. We show that surprisingly affine policies provide the optimal approximation for this class of uncertainty sets that matches the hardness of approximation; thereby, further confirming the power of affine policies. We also provide a faster algorithm to compute near-optimal affine policies.

#### 2 - Robust Queueing Approach to Optimal Control of Fork-join and Replication Systems

Chaithanya Bandi, Kellogg School of Management, Northwestern  
University, 2211 Campus Dr, room 4169, Evanston, IL, 60208,  
United States

We consider the problem of control and analysis of fork-join queues.

#### 3 - A Robust Queueing Network Analyzer Based on Indices of Dispersion

Wei You, Columbia University, New York, NY, 10032,  
United States, Ward Whitt

We present a robust queueing network analyzer (RQNA) algorithm to approximate the steady-state performance of a single-class open queueing network of single-server queues with Markovian routing, allowing general interarrival and service distributions. The RQNA algorithm includes subroutines to (1) approximate system performance measures using the index of dispersion for counts (IDC) of the arrival process at each station, (2) calculate or estimate the IDC's for external flows, (3) solve systems of linear equations to approximate the IDC's for internal flows and (4) eliminate customer feedback. Effectiveness of the RQNA algorithm is supported by heavy-traffic limits and simulations.

#### 4 - Robust Maximum Likelihood Estimation

Omid Nohadani, Northwestern University, 2145 Sheridan Road,  
Technological Institute M233, Evanston, IL, 60208-3119,  
United States, Dimitris Bertsimas

In many applications, statistical estimators serve to derive conclusions from data. However, the conclusions are dependent on uncertainties in the data. We use robust optimization principles to provide robust maximum likelihood estimators that are protected against data errors. We provide efficient local and global search algorithms to compute the robust estimators. The performance is demonstrated on simulated data and on a large set of clinical radiation therapy data, where robust estimators offer more reliable decisions. This approach is general and applicable to a broad range of problems.

## TE38

North Bldg 225B

### Joint Session APS/Practice Curated: Discrete Convexity and its Application

Sponsored: Applied Probability

Sponsored Session

Chair: Linwei Xin, University of Chicago, Chicago, IL, 60637, United States

Co-Chair: Xin Chen, UIUC, Urbana, IL, 61801, United States

#### 1 - Optimal Inventory Management of a Blood Center

Yixuan Liu, University of Texas, 2110 Speedway, B6000, IROM,  
Austin, TX, 78705, United States, Youyi Feng, Guoming Lai

We study inventory management for a blood center that periodically collects whole blood and processes it into multiple blood products including red blood cell and platelet. With limited lifetimes, blood products are stored to satisfy random demands or sold in clearance sales before becoming outdated. The blood center also has an option to replenish red blood cells from an alternative source. Applying the concept of multimodularity, we characterize the structural properties of the value function and the optimal strategies. We demonstrate that the replenishment and salvage decisions can be coordinated to optimize the inventory system and discuss the value of implementing the alternative.

**2 - Substitutability, M-natural-convexity and Their Applications**

Menglong Li, UIUC, Urbana, IL, United States, Xin Chen

Substitutability, an important concept in economics and operations research, poses significant technical challenges. In this paper, we build fundamental properties of M-natural-convexity and its variant SSQM-natural-convexity, and apply them to analyze operations models with substitution: a multi-product multi-period stochastic inventory model and a portfolio contract model where a buyer reserves capacities in blocks from multiple competing suppliers.

**3 - Stochastic Optimization with Decisions Truncated by Random Variables and its Applications in Operations**

Xiangyu Gao, The Chinese University of Hong Kong, Hong Kong, Xin Chen, Zhan Pang

We study a class of stochastic optimization problems with decisions truncated by random variables. We develop a transformation technique to convert the original non-convex problems to equivalent convex ones. Our transformation allows us to prove the preservation of some desired structural properties, such as convexity, submodularity, and L-natural-convexity, under optimization operations, which are critical for identifying the structures of optimal policies and developing efficient algorithms. We demonstrate the applications of our approach to several important models in operations management.

**TE39**

North Bldg 226A

**Joint Session MSOM/Practice Curated: Empirical Studies in Service Operations**

Sponsored: Manufacturing &amp; Service Oper Mgmt/Service Operations

Sponsored Session

Chair: Song-Hee Kim, University of Southern California, Los Angeles, CA, 90089, United States

**1 - Labor Planning and Shift Scheduling in Retail Stores Using Customer Traffic Data**

Marcelo Olivares, Universidad de Chile, Beauchef 851, Santiago, Chile

This work combines empirical analysis of point-of-sales data, customer traffic and employee staffing, with optimization methods to build a decision support tool that can be used by managers to plan labor allocation and working schedules, balancing gross margins, labor costs and employee satisfaction. An econometric model is developed to estimate the effect of labor on sales in an hourly basis, decomposing the effect of labor into conversion and ticket value. The empirical results are used in mathematical program that seeks to find the best feasible schedule to maximize store profitability, accounting for labor regulation restrictions and practical constraints.

**2 - Sooner or Later? Learning from Delivery Speed Information**

Ruomeng Cui, Emory University, 1935 Ridgmont Lane, Decatur, GA, 30033, United States, Tianshu Sun

Online retailers who sell physical products need to inform customers how fast an order can be delivered. The delivery speed is a crucial service metrics that online retailers can easily adjust on the website. On one hand, an aggressive (faster) delivery estimate could meet more demand and thus may increase current sales. On the other hand, it may also raise the likelihood of customers experiencing a loss in time due to a longer than expected wait, which might hurt future sales. Collaborating with an online store selling custom products, we leverage the exogenous shipping policy change and use a difference-in-difference approach to examine whether and how consumers respond to the delivery information.

**3 - Spatially Differentiated Services: Bike-share, Ride-hailing, Etc.**

Karan Girotra, Cornell Tech, New York, NY, 10044, United States

We present the the key common patterns from our findings from collaborations with bike-share operators in Paris and London, ride-hailing companies and a shuttle service operator. We find that there are consistent patterns of commuter behavior and preferences in all these systems and use these patterns to provide guidance on the design of such systems.

**TE40**

North Bldg 226B

**Systems Engineering Decision Analysis**

Sponsored: Decision Analysis

Sponsored Session

Chair: Christian Wernz, Virginia Commonwealth University - VCU, P.O. Box 980205, Richmond, VA, 23298, United States, Virginia Tech, Blacksburg, VA, 24060, United States

**1 - Trade-off Analytics with Quantitative Set-based Design**

Eric Specking, University of Arkansas, 4207 Bell Engineering Center, Fayetteville, AR, 72701, United States, Gregory S. Parnell, Edward A. Pohl

Traditional system design (Point-Based Design), involves identifying and comparing a small number of design solutions. Set-Based Design (SBD) is an alternative approach that evaluates many points in sets of design choices. Repeatable quantitative techniques to perform SBD trade-off analysis of systems do not exist. This presentation will provide insights into SBD quantification literature and demonstrate mathematical methods to perform SBD trade-off analytics. These SBD techniques are enabled by an integrated MBE framework for system trade-off analytics using models and simulations.

**2 - Multi-objective Decision Analysis in Transportation System Planning**

Edward A. Pohl, Professor, University of Arkansas, Department of Industrial Engineering, 4207 Bell Engineering Center, Fayetteville, AR, 72701, United States, Bobby Cottam, Gregory S. Parnell

Decision analysis is important for designing an optimal transportation system. With a large variety of stakeholders, different types of users, and unique a set of considerations for every project multiple objective decision analysis is a useful tool to understand the tradeoffs and values of different alternatives in transportation planning. Resilience is another important consideration in transportation planning, between accidents weather and special events there are numerous times when a system is not functioning at optimal capacity, considering which alternatives perform best under adverse conditions can allow for a consistently higher level of service for travelers.

**3 - An Alternative to Heat-map Risk Matrices for Project Risk Prioritization**

Jamie Peter Monat, Professor of Practice, Worcester Polytechnic Institute, 100 Institute Road, Worcester, MA, 01609-2280, United States, Scott Doremus

Heat map risk matrices are widely used to prioritize risks. They are widely used in projects and programs structured for product development, business, construction, R & D, medicine, and politics. However, they suffer from several weaknesses, notably subjectivity, symmetry, category prioritization reversal, and a failure to account for Risk Aversion. Because of this, they can lead to serious mis-prioritization and mismanagement of risks. We propose an alternative to the standard risk matrix that accounts for these deficiencies and provides a significantly better risk prioritization tool. Two field trials were conducted to demonstrate the benefits of the alternative method.

**4 - Optimal Verification Strategies in Multi-firm Projects: A Multiscale Decision Theory Approach**

Aditya Umesh Kulkarni, Virginia Commonwealth University, 1008 East Clay Street, Box 980203, Richmond, VA, 23298-0203, United States, Alejandro Salado, Christian Wernz

Incentivizing verification activities of sub-contractors in multi-firm projects is a significant challenge for the main contractor. We present a belief-based model of verification that utilizes the multiscale decision theory (MSDT) modeling approach to determine optimal incentives and verification strategies in a multi-firm design project. Exact solution algorithms that determine optimal incentive and verification strategies are then presented for multiple scenarios. Our work contributes to MSDT and systems engineering literature by studying the hitherto unexplored problem of optimal verification and incentive strategies in multi-firm scenarios.

**TE41**

North Bldg 226C

**Decision Analysis and Health Care Policy**

Sponsored: Decision Analysis

Sponsored Session

Chair: Manaf Zargoush

**1 - Predicting Health and Economic Outcomes of Providing Subsidy for Contraception in British Columbia, Canada**

Saied Samiedaluae, University of Alberta, 3-40C Business Building, Alberta School of Business, Edmonton, AB, T6G 2R6, Canada, Steven Shechter, Wendy Norman, Stirling Bryan

Almost half of pregnancies in Canada are unintended. Cost is among the major barriers to effective family planning methods and services. Extending government subsidy for contraception has proven to be a cost-effective intervention in many countries. However, in Canada there is a paucity of evidence to support such programs. In this research, we developed a simulation model that can predict the related health and economic cost and benefit streams likely to result from any policy change in this area, such as provision of universal subsidy for contraception.

## 2 - Support Clinical Decision Making Using Genetic Analytics

Cheng Zhu, McGill University, 701-801 Sherbrooke Est,  
Montreal, QC, H2L 0B7, Canada

Cancer has been one of the most dangerous risk factors to people's health during last few decades. Though there have been several mainstream interventions of cancer, oncologists do NOT have a unanimous decision on the optimal treatment for an individual diagnosed with a cancer. Based on a mRNA sample from the Gene Expression Omnibus (GEO), we are identifying the key modules for PDAC metastasis, in order to provide solid support for clinical decision making.

## 3 - Experience of Disability Among Older Adults

Manaf Zargoush, McMaster University, 1280 Main Street West-  
DSB 204, Hamilton, ON, L8S 4M4, Canada, Farrokh Alemi,  
Somayeh Ghazalbash

Limited information is available regarding the complex sequence of functional change and death for older adults. Clinicians use this information to set priorities for their treatments. Policymakers can use these data to set value-based incentives for care-providers. We fill the gap by using an innovative blend of several data analytics methods based on 1.8M functional assessments of 300K residents in VA Community Living Centers. We report details on the likelihood, duration until next event, and sequence of functional change and death. Such a patient-centric benchmark is vital to ensuring optimal care for persons in nursing home settings and can be used for planning for end-of-life disabilities.

## ■ TE42

North Bldg 227A

### Simulation

Contributed Session

Chair: Xi Chen, Virginia Polytechnic Institute and State University,  
Blacksburg, VA, 24061, United States

### 1 - Four Ways to Kill a Vampire: An Agent-based Simulation of the Emergence of Dominant Technologies

Christian Stummer, Prof., Bielefeld University, Universitaetsstr. 25,  
Bielefeld, 33615, Germany, Michelle D. Haurand

Although superior technologies often establish themselves as a standard in a market, sometimes an inferior one succeeds instead. We have developed an agent-based simulation as a means for studying the corresponding formation processes and for analyzing the effectivity of some management measures (e.g., marketing campaigns). As a field of application, we chose the (fictitious) world of vampires, in which humans must adopt weapon technologies to defend themselves against their supernatural adversaries. In the model, we account for learning effects, word of mouth, and normative social influence.

### 2 - Gradient Based Criteria for Sequential Experiment Design

Collin Erickson, Northwestern University, 2145 Sheridan Road,  
Room C210, Evanston, IL, 60208, United States,  
Bruce Ankenman, Matthew Plumlee, Susan M. Sanchez

Computer simulation experiments are commonly used as an inexpensive alternative to real-world experiments to form a metamodel that approximates the input-output relationship of the real-world experiment. While a user may want to understand the entire response surface, they may also want to focus on interesting regions of the design space, such as where the gradient is large. In this paper we present an algorithm that adaptively runs a simulation experiment that focuses on finding areas of the response surface with a large gradient while also gathering an understanding of the entire surface. We consider the scenario where batches of points can be run simultaneously, such as with multicore processors.

### 3 - A Methodology for Using Simulation as Tools for Collecting Data

Farhad Moeeni, Professor, Arkansas State University, Cit Dept,  
P.O. Box 130, State University, AR, 72467, United States

Data collection is a challenging and time-consuming phase of simulation modeling cycle. The task becomes more challenging when the data is related to human perception or behavior. One common approach for collecting such data has been surveys and interviews. Unfortunately, good survey instruments are hard to design and interviews or open-ended questionnaires are difficult to analyze and quantify. In order to alleviate these shortcomings, we propose a method to apply simulation systems as tools for collecting data on human behavior that otherwise is hard or impossible to collect. We will demonstrate the methodology through an example.

### 4 - A Dual-metamodeling Approach for Robust Optimization in Simulation

Wenjing Wang, Virginia Polytechnic Institute and State University,  
1145 Perry Street, Durham 106, Blacksburg, VA, 24061,  
United States, Xi Chen

In this work, we propose a dual metamodeling approach for robust optimization in simulation. We will investigate different dual-metamodeling approaches for robust optimization in simulation, including a dual Gaussian process model which models the mean and variance response surfaces separately and a variational inference-based heteroscedastic Gaussian process approach that models these two surfaces simultaneously. The performance of the proposed approaches will be demonstrated through numerical examples.

## 5 - An Efficient Morris Method-based Framework for Simulation Factor Screening

Xi Chen, Assistant Professor, Virginia Tech, 1145 Perry Street,  
Blacksburg, VA, 24061, United States

We study the methodological underpinnings of the Morris's elementary effects method, a model-free factor screening technique originally proposed for deterministic simulation experiments, and develop an efficient Morris method-based framework (EMM) for simulation factor screening. Equipped with an efficient cluster sampling procedure, EMM can simultaneously screen the main and interaction (or nonlinear) effects of all factors and control the overall false discovery rate at a prescribed level. We reveal the connections between EMM and other factor screening methods and examine the resulting implications under some commonly stipulated assumptions in design of experiments.

## ■ TE43

North Bldg 227B

### Long-term Sustainable Energy/Power System Expansion Planning

Emerging Topic: Energy and Climate

Emerging Topic Session

Chair: Qipeng Zheng, University of Central Florida, FL, United States

### 1 - A Multistage Decision-Dependent Stochastic Bi-level Programming Approach for Power Generation Investment Expansion Planning

Qipeng Phil Zheng, University of Central Florida, 12800 Pegasus  
Dr., P.O. Box 162993, Orlando, FL, 32816, United States,  
Yiduo Zhan

We propose a bi-level optimization model that includes an upper-level multistage stochastic nonlinear expansion planning problem and a collection of lower-level problems that solves for economic dispatch problems under different scenarios. This model seeks for the optimal sizing and siting for both thermal and wind power units to be built to maximizing the expected profit for a profit-oriented power investor. We design probability distribution functions of decision variables and input parameters based on the economies-of-scale theory in electricity systems. We develop a solution algorithm based on column generation for this program.

### 3 - Proximal-based Dual Decomposition Algorithms With Applications To Capacity Expansion

Run Chen, Purdue University, West Lafayette, IN, United States,  
Andrew Lu Liu

Power grids' planning and operation exhibit extreme multi-scale, ranging from hourly operation to decades of planning. We use proximal-based predictor-corrector enabled dual decomposition to decouple the linkage between different time-scales, proposing a distributed algorithm where primal-minimization is decomposed into massive parallel sub-problems. Convergence is established, as well as the linear convergence rate. Explicit non-anticipativity constraints are used to deal with stochasticity. Applications demonstrate significance of considering ramping constraints in finer time-scale.

## ■ TE44

North Bldg 227C

### Renewable Energy

Sponsored: Energy, Natural Res & the Environment/Electricity

Sponsored Session

Chair: Ming Jin, UC Berkeley, Berkeley, CA, 94720, United States

Co-Chair: Somayeh Sojoudi, University of California-Berkeley,  
Berkeley, CA, 94703, United States

### 1 - Risked Investment in Renewable Electricity Generation

Andy Philpott, University of Auckland, Dept of Engineering  
Science, Private Bag 92109, Auckland, New Zealand,  
Michael C. Ferris

Using data from New Zealand, we discuss models of the national electricity system that will deliver 100% renewable electricity. Wind and solar energy are intermittent, and run-of-river hydroelectricity plants convert uncertain inflows into uncertain levels of energy, so the planning problem must account for these uncertainties. To compensate, hydroelectric reservoirs provide a means of storing energy, and geothermal power provides a predictable base-load energy source. We compare a socially optimal solution with one that arises from competitive equilibrium with risk-averse investors.



## 2 - Leveraging Machine Learning Approach to Optimize the Participation of a Wind and Storage Power Plant

Md. Noor-E-Alam, Northeastern University, 360 Huntington Ave, Boston, MA, 02021, United States, Jose L. Crespo-Vazquez, Jose A. Martinez-Lorenzo, C. Carrillo, E. Diaz-Dorado

In this talk, we will introduce a robust decision making framework for a wind and storage power plant participating in day-ahead and reserve markets. At first we discuss our proposed two-stage convex stochastic model to maximize the net benefit. Then we discuss a number of machine learning techniques used to generate influential scenarios to be used in our proposed stochastic model. Finally, we will share our results obtained from several simulation experiments to evaluate the quality of the proposed stochastic approach using real-world wind farm data.

## 3 - Volatility, A Barrier to Renewable Energy Future

Jingxing Wang, University of Michigan, 1205 Beal Ave., Ann Arbor, MI, 48109, United States, Romesh Saigal, Eunshin Byon, Abdullah Alshelahi

Renewable energies, such as solar and wind, create volatilities in the power system, causing problems for the management of the power grid. The battery technology can be used to stabilize the volatile solar and wind energy power output. We use the principal multi-agent contract theory to model an aggregator who will bid the stabilized wind farm output to the ISO.

## 4 - A Structural Estimation Analysis of the Strategic Switching of Peaking Generators

Stein-Erik Fleten, Norwegian University of Science & Technology, Dept of Ind Econ & Tech Mgmt, Trondheim, Norway, Benjamin Fram, Alois Pichler, Carl J. Ullrich

We analyze the real options to shutdown, startup and abandon peak power plants. The plants' status for a given year is either operating, in standby or retired. The analysis is made using data for 1,121 individual power plants for the period 2001-2009, and peakers in PJM 2001-2016. We estimate the irreversible costs of switching status by structural estimation of a real options model. The results on switching and maintenance costs are new to the literature. There is a marked difference in behavior after the introduction of capacity payments in PJM.

## TE45

North Bldg 228A

## Environment, Energy, and Natural Resources I

Contributed Session

Chair: Tatsuya Ishikawa, IBM Research, New York, NY, United States

### 1 - Modeling and Solving Conservation Management Design Problem

Andres P. Weintraub, Universidad de Chile, Dept De Ingenieria Industrial, Republica 701 Casilla 86-D, Santiago, Chile, Jordi Garcia-Gonzalo, Eduardo Ivarez-Miranda, Virgilio Hermoso, Jos Salgado

We propose a MIP-based framework for modeling and solving a multi-action and multi-species conservation management design problem; we seek for plans that maximize ecological benefit and minimize spatial fragmentation, simultaneously, while ensuring an implementation cost no greater than a given budget. Using a case study from northern Australia, we show how the methodology exploits the trade-offs among the ecological, spatial and cost criteria, enabling to explore and analyze a broad range of conservation plans, and to select the one exhibiting the best quantitative and qualitative outcomes.

### 2 - New Stochastic Cell Based Fire Management Simulator

Cristobal Pais, PhD Student, University of California Berkeley, Berkeley, CA, 94720, United States, Jaime Carrasco, David L. Martell, Andres P. Weintraub, David L. Woodruff

Cell2Fire is a new stochastic cell-based woodland fire spread simulator. Incorporating fuel and fire models from the Canadian Fire Behavior Prediction (FPB) System, it is designed for assessing the impact of harvesting designated forest stands on landscape flammability and expected losses in a heterogeneous landscape. Cell2Fire exploits parallel computations allowing users to run large-scale simulations. It can be easily integrated with harvesting management decision models in order to determine the optimal forestry planning. Real instances are tested and compared to existing state-of-the-art simulators outputs for performance comparison. Future extensions are discussed.

### 3 - Smart Control of Fleets of Electric Vehicles in Smart and Connected Communities

Erotokritos Skordilis, PhD Student, University of Miami, 5202 University Dr, Coral Gables, FL, 33146, United States, Ramin Moghaddas

We present a multi-objective mixed integer-linear program for the electric vehicle (EV) charging scheduling problem. The proposed mathematical framework was developed from the perspective of optimal EV assignment to charging stations between specific time intervals. Static and dynamic model approaches were considered. As solution approaches, the augmented  $\epsilon$ -constraint method and a modified weighted-sum method were utilized. Scheduling results based on a real world charging station network and a large number of simulated EVs are

demonstrated.

### 4 - Real Time Localization of Objects via Passive RFID and KNN with Dynamic Neighborhood Selection Algorithm

Bijoy Dripta Barua Chowdhury, University of Arizona, Tucson, AZ, 85716, United States, Sara Masoud, Young-Jun Son

In this work, a novel localization framework is proposed to localize objects using a real-time, passive Radio Frequency Identification (RFID) system. After generating a statistically adequate regression model based on Received Signal Strength Indicator (RSSI), a fingerprinting database is generated to localize the tags based on dynamic k-nearest neighborhood (KNN) algorithm. The proposed framework continuously updates the models which makes it adaptable to the environmental changes. Experimental results at different scenarios demonstrate the effective performance of the proposed framework for localizing objects in dynamic environments.

### 5 - Sparse Modeling Approach for Optimizing Temperature-sensor Placements in Greenhouses

Tatsuya Ishikawa, IBM Research, Tokyo, Japan, Kenji Komiya

In greenhouse farming, controlling temperature is essential for crop growth. However, farmers often operate thermal equipment without knowing the details of temperature distributions. Deploying a large number of sensors can be a solution but is expensive and obstructive. To minimize the need for such intensive measurements, we developed a model that predicts temperature distributions from a small number of sensors. The sensors are selected using group regularization, such as the multi-task Lasso, that forces the model to reconstruct all sensor values of a pilot deployment from a subset of these values. Our experiments using real-world greenhouse data indicate the effectiveness of our approach.

## TE46

North Bldg 228B

## Natural Gas Markets

Sponsored: Energy, Natural Res & the Environment/Energy

Sponsored Session

Chair: Felipe A. Feijoo, Pontificia Universidad Calotica de Valparaiso, Chile

### 1 - The Economic Impact of Price Controls on China's Natural Gas Supply Chain

Felipe A. Feijoo, Pontificia Universidad Calotica de Valparaiso, Av. Brasil 2241, Office 6-8, Valparaiso, Chile, Bertrand Rioux, Philipp Galkin, Axel Pierru, Frederic H. Murphy, Kang Wu

We developed a Mixed Complementarity Problem (MCP) model of China's natural gas industry. The model was used to design several scenarios to assess how government pricing policies and restricted third party access to midstream infrastructure impacted the supply logistics of China's profit maximizing natural gas firms. We find that lifting the price caps for regulated natural gas demand sectors could yield a 4.7% reduction in total system cost and reduce the national average marginal supply cost by 16%. Liberalized prices combined with improved third party access to pipeline and regasification infrastructure would result in 2.2 billion USD costs saved (7.6%) and a 16% reduction in the spot price.

### 2 - A Framework for Calibrating Transportation Models:

#### A Spatial Price Equilibrium Based Method

Charalampos Avraam, Johns Hopkins University, Felipe A. Feijoo, Richard Poulton, Sauleh Ahmad Siddiqui

The lack of detailed cost data in the Natural Gas sector implies that there will exist more than one calibration that can reproduce a given baseline scenario for a planning model, leading to different responses under the same scenarios. Given the produced, consumed and traded quantities of all modeled regions, we propose a two - stage method for the exact calibration of such models. Stage 1 reconciles the physical system. Stage 2 uses the results of stage 1 and calibrates model parameters using a variation of Spatial Price Equilibrium that exploits the economic interpretation of the dual variables of the model. We implement our method to a transportation model of the North American Natural Gas Market.

### 3 - Locational Valuation of Natural Gas Subject to Pipeline Engineering Constraints

Anatoly Zlotnik, Los Alamos National Laboratory, Aleksandr Rudkevich

We present a pricing mechanism that maximizes social welfare for a pipeline network that delivers natural gas from suppliers to consumers. Engineering constraints on local pressures and energy applied by gas compressors are incorporated. Optimality conditions yield expressions for locational trade values (LTVs) for gas and a decomposition of LTVs into components corresponding to energy, compression, and congestion. We demonstrate that price and pressure differentials between nodes have the opposite sign, so that price cannot decline in the direction of flow, and prove that the pricing mechanism is revenue adequate.

#### 4 - Capturing Industrial Co2 Emissions in Spain: Infrastructures, Costs, and Break-even Prices

Olivier Massol, IFP School & City, University of London, 228 av. Napol on Bonaparte, Rueil-Malmaison, 92852, France, St phane Tchung-Ming, Albert Banal-Estanol

We examine the conditions for the deployment of a largescale CO2 pipeline and storage infrastructure in Spain by 2040. Our approach combines optimization and cooperative game-theoretic concepts. It allows to determine the optimal infrastructure needed to connect a geographically disaggregated set of emitting and storage clusters, along with the threshold CO2 values necessary to ensure that the considered emitters will make the necessary investment decisions. Policy implications derived from this model concern the elaboration of relevant, pragmatic recommendations to envisage CCS deployment locally, focusing on emitters with lower substitution options toward low-carbon alternatives.

## TE47

North Bldg 229A

### Risk-Averse Stochastic Modeling and Optimization

Emerging Topic Session

Chair: Jose Luis Walteros, University at Buffalo, SUNY, 413 Bell Hall, Buffalo, NY, 14260, United States

#### 1 - Risk-Averse Stochastic Modeling and Optimization

Nilay Noyan, Sabanci University, Sabanci University, Orhanli/Tuzla Istanbul, 34956, Turkey

The ability to compare random outcomes based on the decision makers' risk preferences is crucial to modeling decision making problems under uncertainty. In this tutorial, the primary focus is on the stochastic preference relations based on the widely-applied risk measure conditional value-at-risk (CVaR) and the second-order stochastic dominance (SSD). We present single- and two-stage stochastic optimization problems that feature such risk-averse preference relations. We discuss the main computational challenges in solving the problems of interest, and for finite probability spaces we describe alternative mathematical programming formulations and effective solution methods.

## TE48

North Bldg 229B

### Sustainability and the Triple Bottom Line: Social, Environmental (or Ecological) and Financial

Sponsored: Energy, Natural Res & the Environment Environment & Sustainability

Sponsored Session

Chair: Jose Cruz, University of Connecticut, Hartford, CT, 06103, United States

#### 1 - The Sustainable Supply Chain Network Competition with Environmental Tax Policies

Dong Li, PhD, Babson College, Wellesley, MA, United States, Min Yu, Jose Cruz

This model captures different environmental tax policies in a multitiered supply chain network competition context. We investigate the impacts of emission tax policies and product differentiation on competing firms, and compare the effects of different environmental policies on firms' decisions and total emission. The results indicate that the implementation of such policies along with an increase in consumers' environmental concerns can not only motivate the firms to perform sustainable operations, but also reduce the total carbon footprint. This model can be used by firms and policymakers to evaluate the effects of different environmental tax policies in a supply chain competition context.

#### 2 - Risk Sharing Contracts in Sustainable Supply Chains

Shivani Shukla, PhD, University of San Francisco, San Francisco, CA, United States

In this paper, we develop a framework that captures the effects risk sharing contracts in sustainable supply chain management. In particular, we analyze the impact of strategic sharing on supply chain disruption risks and costs and we evaluate the supply chain performance of risk sharing contracts. The numerical examples highlight that it is not a priori clear which participant in the supply chain network will benefit from increased information sharing activities. Our models indicate that the beneficiary of reduced information sharing costs is in some cases dependent on the negotiation power of participants and that it is also dependent on the type of risk sharing contract used.

#### 3 - Quality in Competitive Fresh Produce Supply Chains with Application to Farmers' Market

Deniz Besik, Isenberg School of Management at UMass Amherst, 77 North Prospect, Amherst, MA, 01002, United States, Anna Nagurney

In this paper, we first present explicit formulae for fresh produce quality deterioration based on chemistry and temperature. We then focus on farmers' markets. The popularity of farmer's markets has been growing internationally due to consumers' greater awareness. Farmers' markets, as examples of direct to consumer channels and shorter supply chains, are then studied in the framework of game theory in both uncapacitated and capacitated versions. Illustrative examples in the case of peaches and various scenarios, including production disruptions, in a case study of apples in Massachusetts, provide quantitative evidence of the applicability of our supply chain network approach.

#### 4 - Supply Chain Network Competition Among Blood Service Organizations: A Generalized Nash Equilibrium Framework

Pritha Dutta, University of Massachusetts-Amherst, 9L Brandywine Drive, Amherst, MA, 01002, United States, Anna B. Nagurney

We present a Generalized Nash Equilibrium model of supply chain network competition among blood service organizations which compete for donors and business from hospitals. The model incorporates link capacities, associated arc multipliers to capture perishability, bounds on number of donors, and lower and upper bounds on the demands. The concept of a variational equilibrium is utilized to transform the problem into a variational inequality problem. The proposed algorithmic procedure is applied to numerical examples in order to illustrate the impacts of disruptions on RBC prices, net revenues of the blood service organizations, and their overall utilities.

## TE49

North Bldg 230

### Practice- Game Theory I

Contributed Session

Chair: Ben Hermans, KU Leuven, Naamsestraat 69, Leuven, 3000, Belgium

#### 1 - Spectrum Measurement Markets for Tiered Spectrum Access

Arnob Ghosh, Post-Doctoral Research Associate, Purdue University, 300 N. Grant Street, West Lafayette, IN, 47905, United States,, Randall Berry, Vaneet Aggarwal

The framework for spectrum sharing in the 3.5 GHz band allows for Environment Sensing Capability operators (ESCs) to measure spectrum occupancy to enable commercial users to use this spectrum when it is idle. We consider a scenario in which two spectrum access firms (SAs) seek to access a shared band of spectrum and must purchase spectrum measurements from one of two ESCs. Given the measurements they purchase, the SAs compete on price to serve customers. We consider two cases. When the SAs share the same single band of spectrum, having different qualities of measurements available to different SAs can lead to better economic welfare. When each has a separate licensed band, this difference does not matter.

#### 2 - Coffee Supply Chain Optimization with Respect to Real Value of the Water

Shervin Espahbod, PhD Student, Wilfrid Laurier University, Waterloo, ON, Canada, Michael Houghton

On average, each cup of coffee consumes 500 liters of water. Water footprint clarifies whether the source of water for each product or activity is sustainable or unsustainable. We measured how awareness about water footprint and water taxation of products can shift consumption behavior. First, our behavioral survey explained average global water footprint of verity of coffee. Second, different coffee brands (e.g., Starbucks coffee, Tim Hortons) have different water footprints. With respect to the real value of water that brands consume, they maximize their total profits in an optimal Nash equilibrium.

#### 3 - Two-stage Invest-defend Game: Balancing Strategic and Operational Decisions

Abdolmajid Yolmeh, Rutgers, The State University of New Jersey, 96 Frelinghuysen Road CoRE Building, Room 201, Piscataway, NJ, 08854, United States, Melike Baykal-G rsoy

Protecting infrastructures involves making both strategic and operational decisions. Although usually analyzed separately, these decisions influence each other. To this end, we present a game-theoretic, two-stage model between a defender and an attacker involving multiple target sites. In the first stage, the defender (attacker) allocates investment resources to target sites in order to improve the defense (attack) capabilities. In the second stage, the players decide which target site to defend or to attack. The results reveal that an increase in defense (attack) investments on a target site (increases) decreases the probability of both defending and attacking that target.

#### 4 - Why Low Quality Firms Facilitate P2P Sharing While High Quality Firms do Not

Chenchen Di, UIUC, Champaign, IL, 61820, United States,  
Yunchuan Liu

We study whether and when should a firm actively facilitate consumers' sharing behavior by reducing transaction costs in a competitive market considering consumer usage uncertainty and consumer heterogeneity in transaction costs. This research provides another rationale for seller-induced sharing strategy. We show that seller-induced sharing behavior depends on consumers' usage uncertainty: when consumers face the great uncertainty of future needs, firms can actually benefit from facilitating consumer sharing by making it more convenient. In competitive sharing markets, the low-quality firm will choose to facilitate consumer sharing, and the high-quality firm will not.

#### 5 - Timely Exposure of a Secret Project: Which Activities to Monitor?

Ben Hermans, PhD Student, KU Leuven, Naamsestraat 69,  
Leuven, 3000, Belgium, Herbert Hamers, Roel Leus, Roy Lindelauf

A defender wants to detect as quickly as possible whether some attacker is secretly conducting a project that could harm the defender. The attacker, in turn, schedules his tasks so as to remain undiscovered. One pressing question for the defender is: which activities to focus intelligence efforts on? We model the situation as a zero-sum game, establish that the late start schedule is a dominant attacker strategy, and derive a dynamic program that identifies the defender's optimal response. We evaluate the harm-reduction thanks to each task's intelligence effort by means of the Banzhaf value and illustrate our methods on a nuclear weapons development project.

### TE50

North Bldg 231A

#### Practice- Retail Management I

Contributed Session

Chair: Rachel Rong Chen, University of California-Davis, 3208  
Gallagher Hall, One Shields Avenue, Davis, CA, 95616, United States

#### 1 - Differential Effects of Product Variety on Retailing Performance

Guanyi Lu, Florida State University, Tallahassee, FL, United States,  
Hyunseok Lee, Junbo Son

Using transaction-level data from a local grocery store, we study how different types of product variety affect retailing sales and profit. Our results have managerial implications on product assortment, which may help retailers achieve better performance.

#### 2 - Dynamic Labour Allocation to Improve Store Performance

Shandong Mou, University of Auckland, 12 Grafton Road, Room  
5121, OGGB, Auckland, 1142, New Zealand, David Robb

Despite considerable research on workforce planning, there is limited coverage of real-time labour allocation - a common practice to address real-time mismatches between the demand and supply of labour among departments. We propose a mathematical framework modelling real-time labour allocation and construct heuristics in the context of retail stores. We conduct simulation experiments to compare the performance of heuristics with static and intuitive policies. Simulation results show proposed heuristics outperform other policies.

#### 3 - The Impact of Capacity Changes on Labor Productivity in Retailing

Chien-Ming Chen, Nanyang Technological University-Singapore,  
50 Nanyang Avenue, Singapore, 639798, Singapore,  
Hao-Chun Chuang

Matching in-store staffing level with shopper traffic has been a long-standing principle in retail operations. Using data from a large retail chain, we show that increment of manpower can adversely affect marginal labor productivity in the conversion and sales-generation process. Our findings suggest that managers should be wary of the dark side of capacity increment in the retail environment.

#### 4 - Product Returns, Rebates, and Restocking Fees

Rachel Rong Chen, University of California-Davis, 3208 Gallagher  
Hall, One Shields Avenue, Davis, CA, 95616, United States,  
Eitan Gerstner, Daniele Ragaglia, Paolo Roma

We compare the profitability of rebate and restocking fee policies to manage consumer product returns. We show that the use of rebates can be more profitable than the commonly used restocking fee policy under certain conditions.

### TE52

North Bldg 231C

#### Flash Session III

General Session

Chair: INFORMS, 5521 Research Park Drive, Suite 200, Catonsville,  
MD, 21228, United States

#### 1 - Eco-conscious Returns for Retail

Andrew Downard, Senior Product Manager, Happy Returns,  
1106 Broadway, Santa Monica, CA, 90401, United States

Much of the cardboard used for online shopping is from the high return rates and the inefficiency of individual returns by mail. At Happy Returns, we created a new box-free return model designed for minimal environmental impact. Returns are accepted at a nationwide network of 250+ Return Bars at the beginning of the process and shipped in bulk in reusable packaging to nearby hubs for routing to the most efficient destinations. In this presentation we quantify the environmental impact of box-free returns, and share our vision for making returns even happier for shoppers and for the environment.

#### 2 - A Note on Newsvendor Problem with Optimism Coefficient

Milena Bieniek, Maria Curie-Skłodowska University Lublin,  
Lublin, Poland

We study the satisfying newsvendor problem, where the optimal order quantity is chosen by the maximization of the probability of exceeding the expected profit multiplied by a positive constant. This constant called optimism coefficient can be chosen by the firm's management by preference or by available market opportunities. The coefficient indicates whether we deal with low or high optimistic decision maker. For general demand distribution the results are significantly dependent on this coefficient. The numerical example is given for normally distributed demand.

#### 3 - Minimizing Idle Time and Late Start Time in Surgery Using Simulation

Vikas Agrawal, Jacksonville University, 204 Ann Scott Drive,  
Saint Johns, FL, 32259, United States, Aber Elsaleiby, Yue Zhang,  
P. Sundararaghavan, Andrew Casabianca

In this paper, we address a surgery scheduling problem in a hospital setting. Typically surgeries can be started only on or after the scheduled start time. Given that surgery time is stochastic in nature, it can go beyond the scheduled finish time in which case the next scheduled surgery will be delayed. Likewise, a surgery can be finished earlier than the scheduled finish time in which case the operating room will remain ideal until the start of next scheduled surgery. Both of these situations are undesirable. For this problem, we develop a simple method to assign start times so as to minimize the sum of idle times of the OR and late start times of the surgeries.

#### 4 - Approximating Maximin Fair Guarantee

Setareh Taki, University of Illinois at Urbana-Champaign,  
Champaign, IL, United States, Jugal Garg

We present new results in allocating indivisible items to agents which is within a constant factor of their maximin share.

#### 5 - Using Real-time Operational Data to Increase Labor Productivity in Retail

Pablo Jofr, Universidad de Chile, Beaucheff 851, Santiago,  
8370456, Chile, Marcelo Olivares, Andres I. Musalem

This research is focused on developing models to support dynamic systems that can reassign labor to different activities. This work utilizes data from a pilot study in a store of a home improvement retail chain in the U.S. Security cameras were used to track the number of customers and employees on different sections. We use these operational data to measure - in real time - the demand for services in a specific store department, and the service capacity. This information can be linked to point of sales data, to measure the effect of the number of employees on the sales of specific departments. All this provide information for a dynamic labor allocation system in order to prioritize where to allocate employees.

#### 6 - A Grounded Theory Model for Big Data in Supply Chain

Mohammad Baitalmal, PhD Candidate, University of North Texas,  
Denton, TX, 76210, United States  
Mohammad Baitalmal, PhD Candidate, King Saud University,  
Riyadh, Saudi Arabia, Victor R. Prybutok, Abdulrahman Habib

This research investigates the big data phenomena within supply chain and logistics using interviews to undertake a grounded theory approach. The current state of the literature indicates a gap in understanding the impact of big data's emergence on the supply chain. To answer the call of Waller and Fawcett (2013) for detailed inductive research to understand changes in the supply chain as a result of using big data. The results of this research provide a theoretical framework that relates big data and the supply chain.



### 7 - A Novel Dynamic Routing Framework for Shared Mobility Services

Yue Guan, PhD. Candidate @ MIT, Massachusetts Institute of Technology, 77 Massachusetts Avenue, Room 3-339K, Cambridge, MA, 02139, United States

Shared Mobility on Demand (MoD) services like Uber, Lyft, and Didi have shown that a continuum of solutions can be provided between traditional private transport and public mass transit. Here we propose a novel shared MoD framework which generates a dynamic route for multi-passenger transport, using a new concept of space window that introduces a degree of freedom to help reduce system cost in designing the optimal route. An Alternating Minimization based algorithm is developed. Its analytical properties are characterized. Detailed computational experiments are carried out that demonstrate its advantages in computational efficiency and optimality compared to standard optimization solvers.

### 8 - Dynamic Capabilities for Sustainable Smart Cities

Abdulrahman Habib, University of North Texas, 1404 Sombre Vista Drive, Denton, TX, 76205, United States, Victor R. Prybutok

This study explores the application of dynamic capabilities in smart city parking solutions. Dynamic capabilities theory includes a cycle of *æsense*, *æseize*, *æalign*, and *ætransform*. In the posited model the city can *æsense* problems and *æseize* data to make it available for data mining and machine learning that *ætransforms* the problems in parking and allow solutions. Sensing allows ongoing data evaluation and provides an opportunity for continuous quality improvement. This approach *æaligns* with a comprehensive sustainable smart city strategy.

### 9 - Fast Computation of Global Solutions to the Single-period Unit Commitment Problem for Electricity Market Applications

Zhibin Deng, University of Chinese Academy of Sciences, 80 E. Zhong Guan Cun, BLVD 7 RM 221, Beijing, 100190, China

The single-period unit commitment problem has significant applications in electricity markets. This paper proposes an extremely efficient global optimization algorithm for solving the problem. We propose a conjugate function based convex relaxation and design a special dual algorithm to compute a tight lower bound of the problem in  $O(n \log n)$  complexity. Computational experiments show that the proposed algorithm solves test instances with 500 integer variables in less than 0.01 seconds, whereas current state-of-the-art solvers fail to solve the same test instances in one hour.

## ■ TE53

North Bldg 232A

### Multi-unit Auctions

Sponsored: Auction and Marketing Design

Sponsored Session

Chair: Kyle Woodward, University of North Carolina at Chapel Hill, Chapel Hill, NC, 27599-3305, United States

#### 1 - Multi-product Supply Function Equilibria

Par Holmberg, Research Institute of Industrial Economics, Grevatan 34, Stockholm, SE10215, Sweden, Keith Ruddell, Bert Willems

We solve for Nash equilibria in a procurement auction with two heterogeneous divisible goods and a uniform price for each good. There are (dis)economies of scope in production and goods could be substitutes or complements for the procurer. Before demand is realized, each firm offers a vector of supply functions where supply of a good depends on the prices of both goods. We show that payoffs and the allocation of underlying goods are invariant to bundling. For quadratic costs and linear demand, bundles can be chosen such that it is equivalent to trade divisible packages in two separate auctions. Such packaging simplifies the analysis of and the operation of a multi-product auction

#### 2 - Random Mechanisms for the Sale of Divisible Goods

Kyle Woodward, University of North Carolina at Chapel Hill, Department of Economics, Gardner Hall, CB #3305, Chapel Hill, NC, 27599-3305, United States

Uniform-price and discriminatory auction formats are used to allocate many divisible commodities, but which of these two formats generates better outcomes is both theoretically and practically ambiguous. I investigate mechanisms which are convex combinations of these two formats. I provide a characterization of equilibrium in this model, and prove uniqueness of equilibrium in a natural class. With linear marginal values, the discriminatory auction strictly revenue-dominates any convexification of the two auction formats. I show that the equilibrium multiplicity of the uniform-price auction smoothly disappears as the convexification tends toward a discriminatory auction.

### 3 - Coordinating Capacity Negotiations In Semiconductor Industry

Ankit Bansal, North Carolina State University, 304, Daniels Hall, 111 Lampe Drive, Raleigh, NC, 27695, United States, Reha Uzsoy, Karl Kempf

We model the negotiations between multiple product development groups (PDGs) and a manufacturing group (MFG) for access to manufacturing capacity to support product development activities in the semiconductor industry. We develop an iterative combinatorial auction framework based on Lagrangian relaxation that maximizes corporate profit subject to the resource constraints of both organizations. We consider the case when MFG and PDGs receive limited budgets from corporate management who acts as a trader for both groups. The approach aims to achieve coordinated decisions between the two groups with reasonable duality gaps and constrain them to behave truthfully in the negotiation framework.

### 4 - Refund Of Uncertainty-reducing Project Preparation In Procurement Auctions

Marion Ott, RWTH Aachen University, Templergraben 64/V, Aachen, 52062, Germany, Karl-Martin Ehrhart, Ann-Katrin Hanke

This paper analyzes second-price procurement auctions in which bidders can take costly pre-auction measures that reduce their uncertainty about their costs for their offered good or service. An example is project preparation for auctions for renewable energy support. The measures are either mandatory or optional prior to the auction, but need to be taken prior to project realization. For both cases, we investigate the effect of a refund of the costs for the measures by the auctioneer on his procurement costs, on the participation level in the auction, and on the probability of an efficient outcome. We compare different refunding options.

## ■ TE55

North Bldg 232C

### Managing Innovation in Novel Contexts

Emerging Topic: New Product Development

Emerging Topic Session

Chair: Xiaoyang Long, University of Wisconsin-Madison, Madison, WI, United States

#### 1 - Optimal Incentive Contracts in Project Management

Anyan Qi, The University of Texas at Dallas, 800 W. Campbell Rd SM 30, Richardson, TX, 75080, United States, Milind Dawande, Ganesh Janakiraman, Qi Wu

We study the contract-design problem faced by a firm for executing a project consisting of multiple tasks, each of which is performed by an individual contractor whose efforts (work-rates) are not observable. We study the case when these tasks can be performed in parallel as well as the case when they have to be performed sequentially.

#### 2 - Do Business Method Innovations Create Value. A Study of Public U. S. Firms in Manufacturing and Distribution

Tian Chan, Emory University's Goizueta Business School, 1300 Clifton Road, Atlanta, GA, 30322, United States, Anandhi S. Bharadwaj, Deepa Varadarajan

Ever since Amazon patented their "1-click" ordering method, there has been significant interest in understanding the value potential of business method patents. In this study, we examine the impact of business method patents on the financial performance of public US manufacturers and distributors, and find that firms investing in high-quality business method patents generate higher market value.

#### 3 - Patent Grant Delays and Inventors' Future Patenting

Param Pal Singh Chhabra, Student, Georgia Institute of Technology, 800 West Peachtree NW, Atlanta, GA, 30308, United States, Manpreet Singh Hora, Karthik Ramachandran

Patent grant delays have the potential of negatively affecting future patenting activities of inventors. Utilizing patents application data, spanning more than three decades, published by the USPTO, we verify this negative relationship. Our results also confirm that the negative relationship is more pronounced in lone-inventors (as compared to teams), and co-inventors (as compared to a prime inventor) in a team.

#### 4 - Employee Mobility and Process Innovation in Manufacturing

Fabian J. Sting, University of Cologne, Albertus-Magnus-Platz, c/o WiSo-Sekretariat Universitaetsstrasse 91, Cologne, 50923, Germany, Philipp Benjamin Cornelius, Bilal Gokpinar

Production employees can be a valuable source of innovative ideas to improve operational efficiency. We empirically investigate how mobility affects the innovation value created by those employees. We examine the immediate and long term (static and dynamic) implications as well as the role of direction of employee moves on innovation outcomes.

## ■ TE56

West Bldg 101A

### Decision-making in Drug Research and Development

Sponsored: Health Applications

Sponsored Session

Chair: Alba Rojas-Cordova, Southern Methodist University, Dallas, TX, 75219, United States

#### 1 - An Approximation Approach for Response Adaptive Clinical Trial Design

Vishal Ahuja, Southern Methodist University, Cox School of Business, P.O. Box 750333, Dallas, TX, 75275, United States, John R. Birge

Multi-armed bandit problems exemplify the exploration vs. exploitation tradeoff. For many practical problem, the state space is intractably large, rendering exact solution approaches impractical. We propose a novel approximation approach that combines grid-based techniques, simulation, and methods to improve approximation accuracy, to obtain near-optimal solutions with minimal added computational burden.

#### 2 - Drug Shortages and Pharmaceutical Supply Chain Reliability

Emily L. Tucker, University of Michigan, Ann Arbor, MI, 48105, United States, Mark S. Daskin, Burgunda V. Sweet, Wallace J. Hopp

A major barrier to effective patient care is drug availability. Shortages within the United States are prevalent and are largely driven by supply chain resiliency decisions. We present a new model of pharmaceutical supply chain reliability to analyze the effect of design decisions on drug availability. We discuss competitive extensions.

#### 3 - Analysis of Medicines Shortages in Europe

Vincent Hargaden, University College Dublin, School of Mechanical & Materials Engineering, Engineering & Materials Science Centre, Belfield, DUBLIN 4, Ireland, Rachel Ward, Eoghan O'Reilly

The issue of medicines shortages across Europe has been receiving increased attention recently from governments, regulatory agencies and healthcare providers. We report on the work of a European Union research project "European Medicines Shortages Research Network - Addressing Supply Problems to Patients", funded by the Cooperation in Science and Technology (COST) program. This talk will focus on approaches (e.g. system dynamics) and analysis of the downstream supply chain issues which lead to shortages at both hospital and community pharmacies.

#### 4 - Adaptive Trial Supply Optimization

Wei-An Chen, Purdue University, Weldon School of Biomedical Engineering, MJIS Building, Room 1052, West Lafayette, IN, 47907-2032, United States, Nan Kong

As adaptive clinical trials receive growing attention, they incur additional challenges to drug supply chain management. Targeting on commonly-used adaptation schemes, size re-estimation and dosage dropping, we developed a stochastic production-inventory-distribution optimization model under participant enrollment and trial size uncertainty, which addresses important aspects such as trial span, resupply policy, drug wastage. Our numerical study shows our model can deliver promising operational responses from the supply chain aspect to the trial design adaptiveness.

## ■ TE57

West Bldg 101B

### Joint Session HAS/DM: Modeling for Complex Conditions: Acute and Chronic

Sponsored: Health Applications

Sponsored Session

Chair: Julie Simmons Ivy, North Carolina State University, Raleigh, NC, 27695-7906, United States

#### 1 - Handling Missing Data in Severity of Illness Score Development: The Knowledge of Missing Information Combined with Imputation Improves Predictive Power

Joseph Kapena Agor, North Carolina State University, Raleigh, NC, 27606, United States, Osman Ozaltin, Julie Simmons Ivy, Muge Capan, Ryan Arnold, Santiago Romero-Brufau

The objective of this work is to quantify the impact of missing and imputed variables on the performance of prediction models used in the development of sepsis-related severity of illness scoring systems using EHR data. We find that there is a significant increase in performance when moving from models that do not indicate missing information to those that did ( $p$ -value $\leq 0.001$ ). This

increase is higher in models that use summary scores compared to those that use all variables as predictors. We conclude that there is important clinical information in the fact that certain fields are missing in EHR data and the development of scoring systems can perform better by considering which variables are missing.

#### 2 - Real-time Prediction Of Sepsis In Hospitalized Adults Using Continuous Bedside Physiological Data Streams

Franco van Wyk, University of Tennessee, Knoxville, TN, United States, Anahita Khojandi, Robert L. Davis, Rishikesan Kamaleswaran

Sepsis is an acute, life-threatening condition, often acquired in the hospital. Undetected, sepsis can progress to severe sepsis and septic shock, with a risk of death as high as 30% to 80%. Early detection of sepsis can improve patient outcomes. We use a multi-layer machine learning algorithm to analyze continuous, high frequency physiological data, such as vital signs, to identify at risk patients before sepsis onset. In our analysis of a cohort of 1,300 patients, the model only failed to predict 3.16% of sepsis patients earlier than Systemic Inflammatory Response Syndrome (SIRS) criteria. Sepsis patients were predicted on average 211.47 5.08 minutes earlier than SIRS criteria.

#### 3 - A Machine Learning Model to Predict Adult Inpatient Death, Cardiac Arrest, and ICU Transfer

Andres Garcia-Arce, Geisinger, Danville, PA, United States, John McIlwaine, Jason S. Puckey

There is a growing interest in including big data analytics into clinical decision support tools. This project involves the use of electronic records from 79,232 Geisinger patients to create a new early warning score (EWS) using machine learning algorithms. The new model predicts sudden death, cardiac arrest and unplanned transfers to the ICU. This model is expected to outperform other models such as MEWS and NEWS. By having a better EWS, Geisinger clinicians can better plan patient care and hopefully mitigate the effects of adverse events, improving patient outcomes and patient experience.

## ■ TE58

West Bldg 101C

### Joint Session HAS/ICS: Stochastic Modeling and Control in Health Care

Sponsored: Health Applications

Sponsored Session

Chair: Amin Khademi, Clemson University, Central, SC, 29630, United States

#### 1 - Optimal Pooling Schemes for Prevalence Estimation of Emerging Infections

Ngoc Nguyen, PhD Candidate, Virginia Tech, 1145 Perry Street, 210 Durham Hall, Blacksburg, VA, 24061, United States, Ebru Korular Bish, Douglas R. Bish

Accurate prevalence rate estimation is essential for surveillance of infections and diseases, and is typically conducted via pooled testing. The pooling design, i.e., the number and sizes of testing pools, impacts the estimation accuracy. However, determining an optimal pooling design requires an a priori estimate of the unknown prevalence rate, and can be challenging, especially for emerging infections with limited information. We develop robust optimization models and characterize structural properties of optimal pooling designs for surveillance. Our case study suggests that estimation accuracy can be substantially improved through optimal pooling designs.

#### 2 - Proportional Fairness Model of the Allocation for Heart Transplantation System

Farhad Hasankhani, Clemson University, Clemson, SC, United States

The allocation process of scarce resources such as donor hearts should be managed to be distributed efficiently and fairly among patients demanding transplant. In order to model fairness in heart allocation, we define utility of each patient as their total life-expectancy and use proportional fairness notion to develop an optimization problem. Objective function is the sum of logarithm of expected utilities of patients in which expected utilities are quadratic functions of the decision variables. The solution of the optimization problem characterizes the structure of the optimal fair allocation rule.

#### 3 - Antiretroviral Therapy Success

Huaiyang Zhong, Stanford University, Stanford, CA, 94305, United States

Thanks to the success of antiretroviral therapy (ART), HIV has become a chronic disease. Different individual characteristics such as sex, age and race, comorbidities conditions, and drug response history may lead to different optimal choices of ART regimens for a patient in different time periods. Our research aims to provide a personalized HIV treatment plan for patients based on individual characteristics, medical history and other information in patients' electronic medical records.

#### 4 - Proactive Dynamic Alteration of Hospital Operations Under Severe Weather Events with Forecast Updates

Mahsa Ghanbarpour, Northeastern University, 360 Huntington Ave, Boston, MA, 02215, United States, Ozlem Ergun

Preparedness and response planning are necessary to reduce the adverse impacts of severe weather and other environmental emergencies. This study introduces a decision-making framework that optimizes the level and timing of proactive actions by analyzing the trade-offs between making more accurate decisions with better weather forecasts vs. increasing cost of action as the event approaches. This tradeoff is captured by a stochastic dynamic programming. In this study, our aim is to apply this framework to cancel pro-actively and dynamically elective surgeries in anticipation of a snowstorm, with the goal of reducing the negative impact of the event before, during, and after the event.

### ■ TE59

West Bldg 102A

#### Data-driven Decision Making in Pharmaceutical and Healthcare Supply Chains

Sponsored: Health Applications

Sponsored Session

Chair: Hui Zhao, Pennsylvania State University, University Park, PA, 16802, United States

Co-Chair: Liang Xu, Pennsylvania State University, State College, PA, 16801, United States

#### 1 - Analysis And Optimization in Recruitment Stocking Problems

Anh Tuan Ninh, 1604 Queens Crossing, Williamsburg, VA, 23185, United States, Yao Zhao, Benjamin Melamed

We study a new class of inventory control problems, the recruitment stocking problem (RSP), with applications to general recruitment systems, such as clinical trials, product sampling, and sales of products with limited supplies.

#### 2 - Informing Pharmaceutical Regulation Through Economic Modeling and Predictive Analytics

Matthew Rosenberg, US Food and Drug Administration, Silver Spring, MD, United States

The Food and Drug Administration (FDA) is the regulatory agency responsible for ensuring that prescription and over-the-counter pharmaceuticals are safe, effective, and of high manufacturing quality. As part of fulfilling its mission, FDA makes decisions that impact the supply chain, the marketplace, and public health. In this presentation, I will provide examples of research projects that have informed FDA's regulatory decisions; examples may be drawn from topics such as generic drug competition and resource capacity planning. I will also highlight potential opportunities for future collaboration with academic researchers.

#### 3 - Outcome-based Reimbursement for Pharmaceuticals with Uncertain Effectiveness

Liang Xu, Pennsylvania State University, 419A Business Building, Penn State University, State College, PA, 16801, United States, Hui Zhao, Hongmin Li

Insurers usually have to decide whether to cover an expensive new drug and the corresponding co-payment, given the uncertainty of the drug's effectiveness among general patients in clinical practices. As a result, insurers assume great risk of spending a substantial amount of money on drugs which may turn out not to deliver the intended health benefits. This paper investigates how the outcome-based reimbursement (OBR) scheme mitigates such risk and its impacts on the manufacturer, the insurer and patients.

### ■ TE60

West Bldg 102B

#### Resource Allocation and Capacity Management

Sponsored: Health Applications

Sponsored Session

Chair: Mahesh Nagarajan, University of British Columbia, University of British Columbia, Vancouver, BC, V6T 1Z2, Canada

Co-Chair: Yichuan Ding, University of British Columbia, Vancouver, BC, V6T 1C3, Canada

#### 1 - How Early is Too Early for a Preemptive Kidney Transplant? An MDP-Based Retrospective Analysis

Masoud Barah, PhD Candidate, University of Tennessee, 524S John D. Tickle Building,, 851 Neyland Drive, Knoxville, TN, 37996-2315, United States, Murat Kurt, Anahita Khojandi, Bekir Tanriover

Living-donor preemptive kidney transplantation provides survival and financial benefits. We consider transplant timing decisions for chronic kidney disease patients, and develop an MDP model in which patient's evolving health is defined by glomerular filtration rate. We apply the model to identify optimal transplant decisions and associated survival outcomes for patients who received kidney transplants preemptively in US between 2000-2017, and compared the results with their actual counterparts.

#### 2 - Evaluating the Importance of Non-facetime Work in Patient Panel Complexity

Michael Hu, MIT, Cambridge, MA, 02139, United States, Joe Doyle, Stephanie Eisenstat, Retsef Levi

Primary care physicians (PCPs) have traditionally been paid according to activities-based compensation models. Health systems are now moving to patient panel-based payments. This requires determining the workload associated with different patient panels. Until now, panels have been evaluated using risk scores that measure clinical complexity. However, risk scores do not capture non-facetime work, such as visit documentation & staff communication, which consumes substantial PCP time. We demonstrate that risk scores do not accurately measure the workload of patient panels. We then create prediction models that reliably estimate the workload required to manage different patients.

#### 3 - Online Bed Assignment with Uncertain Length of Stays

Van-Anh Truong, Columbia University, 500 West 120th Street, 338 Mudd Hall, New York, NY, 10027, United States, Sicong Li

We study a resource-allocation problem that commonly arises in service settings. In these settings, there is a finite set of resources available over a horizon. Customers arrive over time, each of whom requires a resource for some duration of time that is possibly random, depending on his or her needs. The system collects a reward whenever it assigns a customer to a resource for the entire duration of need. This problem arises in a number of service applications, including healthcare and transportation applications.

#### 4 - A Centralized Allocation Mechanism for Public Housing

Weihua Zhang, University of British Columbia, Vancouver, BC, V6T 2G9, Canada, Yichuan Ding, Daniel Granot

In 2014, US programs of federal rental assistance helped nearly five million families. We model the affordable housing allocation problem as a centralized decision problem. The HA strives to accommodate move-in requests as well as requests of transfer between housing types. We assume that households list the housing types that they would accept without specifying their complete preference order. We further assume that the housing units of each type are homogeneous. For minimizing vacancy rate and maximizing portability (the responsiveness of the HA to households' accommodation requests), we formulate the problems as network flow problems and characterize the optimal solutions.

### ■ TE61

West Bldg 102C

#### Models and Methods for Healthcare Operations and Policies

Sponsored: Health Applications

Sponsored Session

Chair: Xiang Zhong, PhD, University of Florida, Gainesville, FL, 32611, United States

Co-Chair: Michelle Alvarado, University of Florida, Gainesville, FL, 32611, United States

#### 1 - A Finite Capacity Queuing Network Model for Analysis of Patient Transitions within Hospitals

Hyo Kyung Lee, University of Wisconsin-Madison, Madison, WI, United States, Albert J. Musa, Philip A. Bain, Christine Baker, Jingshan Li

Although patient transfer plays a critical role in providing the continuity of medical care, the impact of transitions is often undertaken. Thus, we present a queueing network model to analyze patient transitions between emergency department, intensive care unit, and general ward within a hospital. Routings with feedback flows are considered under general arrival and service processes and the effects of blocking on performance measures are presented. In addition, the impacts of bed capacity, admission rate, as well as system variabilities, are discussed to seek managerial insights.



## 2 - A Dynamic Call-in Control for Unpunctual and Impatient Customers

Yunzhe Qiu, Washington University in St. Louis, 1 Brookings Dr., St. Louis, MO, 63130, United States, Jie Song

Motivated by the increasing demand for health care service and uncertainty of patient arrivals, we propose a real-time dynamic appointment scheduling system with heterogeneous customers whose sensitivity to the waiting time are varied. We construct a continuous time Markov Decision Process in a finite horizon, and derive a myopic optimal policy with the switching-line based on the current information to minimize the total waiting cost. The main finding is the widely used FCFS policy is optimal within homogeneous customers but not optimal if heterogeneity is allowed. An empirical study based on the Pediatric clinic of the Peking University Third Hospital validates our results.

## 3 - A Simulation Optimization Approach to Nursing Home Capacity Planning with Residents Heterogeneity

Xuxue Sun, University of South Florida, Tampa, FL, 33620, United States, Nazmus Sakib, Nan Kong, Chris Masterson, Hongdao Meng, Kathryn Hyer, Mingyang Li

With rapid population aging and overwhelming acute care utilization at hospitals, nursing homes (NHs) are responsible for meeting with the excess demand and increasing acuity of older adults. Successful NH care preparedness becomes significant yet challenging, since NH residents suffer from diverse chronic diseases and functional disabilities, and the service need of each resident varies over time. This work proposes a simulation optimization approach to determining the optimal bed number and staff capacities subject to the heterogeneous service demand.

## 4 - Hospital Readmission Reduction Strategy Using Stochastic Programming

Behshad Lahijanani, University of Florida, 303 Weil Hall, P.O. Box 116595, Gainesville, FL, United States, Michelle M. Alvarado

The Hospital Readmission Reduction Program (HRRP) aims to reduce hospital readmissions by applying a financial penalty to hospitals whose readmission rates are worse than their peer group median. We develop a stochastic program with probabilistic constraints for the hospital's optimal care strategy in response to HRRP. The model maximizes the hospital's profit and utilizes probabilistic constraints to control uncertain readmission probabilities across all patients. Additionally, we explore the impact of penalty and incentive HRRP designs on the hospital's profit and care strategies.

## TE62

West Bldg 103A

### Joint Session DM/Practice Curated: Data Science in Health Care I

Sponsored: Data Mining

Sponsored Session

Chair: Kaiye Yu, Tsinghua University, Beijing, 100084, China

## 1 - A Multi-task Warped Gaussian Process Learning for Predicting the Optimal Next Line of Therapy in Multiple Myeloma

Emisa Nategh, PhD Student, University of Washington, Dept of Info Systems & Operations Management, Michael G. Foster School of Business, Seattle, WA, 98195-3226, United States, David Coffey, Hamed Mamani, Yingfei Wang

The objective of this research was to develop a model to predict the sequence of therapy which results in the best progression free survival (PFS). In this paper, we formulate the next line of treatment PFS based on previous line of treatment PFS and its effect on overall survival as a multi-task learning problem in the context of warped Gaussian process. We propose a novel methodology by using composite kernel over tasks in our model to improve our result. We illustrate its practicability by applying it to sequencing of therapy in cancer patients.

## 2 - Making Predictions of Pediatric Outpatient Clinic Room Requirements to Improve Room Allocation Policies

Tian He, Graduate Student, University of Pittsburgh, 3700 Ohara St, 1025 Benedum Hall, Pittsburgh, PA, 15261, United States, Kiatikun Louis Luangkesorn, Pranay Mohanty

Children's Hospital of Pittsburgh provides space for over 20 specialty outpatient pediatric clinics on site. These clinics have been having issues with patient access, the ability of patients to schedule an appointment in a timely fashion. While the specialties state that lack of additional space prevents them from increasing capacity, the rooms are currently underutilized on the whole. We develop and apply predictive models based on data found in Electronic Health Records to identify on a session by session basis the presence of excess room which could be reallocated to services that require additional rooms to meet known demand.

## 3 - A Data Driven Analytical Framework for Hospital Readmission Prediction

Kaiye Yu, Tsinghua University, Room 520, Shunde Building, Beijing, BJ100084, China, Xiaolei Xie

The improvement effort to reduce hospital readmissions necessitates reliable risk prediction tool. We develop and validate an analytics framework for predictive modeling of all-cause readmissions using data-driven approaches. Dimensionality reduction, predictors identification, data sampling and imbalance data handling are performed. A mix-ensemble framework which is integrated by the base machine learning classifiers is proposed after the comparison of the different prediction techniques using hospital administrative data. Finally, the models are assessed and managerial insights are obtained.

## 4 - A Data Driven Analytical Framework for Hospital Readmission Prediction

Kaiye Yu, Associate Professor, Tsinghua University, Beijing, China, Xiaolei Xie

The improvement effort to reduce hospital readmissions necessitates reliable risk prediction tool. We develop and validate an analytics framework for predictive modeling of all-cause readmissions using data-driven approaches. Dimensionality reduction, predictors identification, data sampling and imbalance data handling are performed. A mix-ensemble framework which is integrated by the base machine learning classifiers is proposed after the comparison of the different prediction techniques using hospital administrative data. Finally, the models are assessed and managerial insights are obtained.

## TE63

West Bldg 103B

### Joint Session DM/Practice Curated: Data Science for Forecasting

Sponsored: Data Mining

Sponsored Session

Chair: Guangrui Xie, Virginia Tech, Blacksburg, VA, 24061, United States

## 1 - A Data-driven Forecasting Approach for Newly Launched Seasonal Products

Tugba Efendigil, MIT, Cambridge, MA, United States, Vicky Wing Kei Chan, Majd Kharlan

Demand forecasting is becoming a very complicated process in fashion industry due to the short product life-cycle, the obsolescence of the retail calendar, and the lack of information for newly launched seasonal items. Therefore, this study focuses on demand prediction with a data-driven perspective both leveraging machine-learning techniques and identifying significant predictor variables to help fashion retailers achieve better forecast accuracy.

## 2 - Sparse Reduced-rank Regression with Applications

Haileab Hilafu, Assistant Professor, University of Tennessee, 916 Volunteer Blvd, Knoxville, TN, 37996, United States

We present a sparse estimation of the reduced-rank multivariate regression model. Our estimation proposal minimizes the block- $\ell_{1,1}$  norm of the rows of the coefficient matrix subject to a sparsity inducing  $\ell_{1,\infty}$  norm. Extensive simulation results will be presented to demonstrate effectiveness of the method. We apply the method to build a predictive model for the interest rates time series covering treasuries, corporate, term spreads and public-private spreads, from the FREDQD data. Theoretical properties of the proposed method will also be presented.

## 3 - An Adaptive Data Communication Scheme for Bandwidth Limited Residential Load Forecasting

Guangrui Xie, Virginia Polytechnic Institute and State University, 112 Durham Hall, 1145 Perry Street, Blacksburg, VA, 24061, United States, Xi Chen, Yang Weng

While adding new capabilities, the proliferation of distributed energy resources makes it challenging to provide reliable power and voltage forecast for operational planning purposes. We propose an integrated Gaussian Process-based method (IGP) for hourly electric load forecasting, which utilizes not only the data streams generated by the target customer but also those of relevant customers in the feeder system. An adaptive data communication scheme is further proposed to maintain the high forecast accuracy of IGP when a data communication bandwidth constraint is imposed in some feeders. The superior efficacy of IGP and the adaptive data communication scheme is tested on various IEEE test cases.

## ■ TE64

West Bldg 104A

**Dynamic Control, System Dynamics, and Neural Networks**

Sponsored: Data Mining

Sponsored Session

Chair: Davood Hajinezhad, Iowa State University, Ames, IA, 50010, United States

- 1 - Learning the Best Metaheuristic Parameters Set for Car-passenger Matching Problem in on Demand Mobility Services**  
 Arslan Ali Syed, Bayerische Motoren Werke, Munich, 81375, Germany, Univ. der Bundeswehr, Munich, Germany, Klaus Bogenberger

Metaheuristics provide good suboptimal solution to an optimization problem in a reasonable time, but extensive effort is required to select a good set of parameters to obtain reasonable performance. In this work we propose that a neural network could be trained that takes specific features of the problem instance and outputs the best parameters for a specific metaheuristic algorithm. We extract various features for car-passenger matching problem to train a neural network that depending on problem instance returns the best metaheuristic parameters set.

- 2 - Distributed Reinforcement Control Learning Using Function Approximation**

Davood Hajinezhad, Duke University, 4225 Larchmont Road, 835, Durham, NC, 27707, United States, Michael Zavlanos

In this research we consider the Reinforcement Learning (RL) problem in a distributed network, and propose a primal-dual optimization algorithm to obtain the parameters of a possibly nonlinear function such as neural networks which approximates the action-value function of the underlying RL problem. Utilizing this we are able to achieve the optimal policy for all agents in the network. The proposed algorithm is incremental and online with provable convergence to the set of stationary solutions.

- 3 - Evaluating Recurrent Neural Networks as a Tool for Process Theory Testing**

Nicholas Evangelopoulos, University of North Texas, Denton, TX, United States, Anna Sidorova

Past events are often the best predictors of the future. Yet, the ability of management scholars to develop process theories is limited by the paucity of statistical tools for testing them. Here we examine the feasibility of Recurrent Neural Networks (RNN), a class of neural networks used for predicting future values based on sequences of historical data, as tools for process theory testing. Using data from SourceForge.net we evaluate selected propositions of the Event System Theory as they apply to the Free/Libre Open Source Software domain using RNN. Methodological recommendations and challenges associated with using RNN for process theory testing are discussed.

## ■ TE65

West Bldg 104B

**Joint Session DM/Practice Curated: Data Science and Deep Learning IV**

Sponsored: Data Mining

Sponsored Session

Chair: Junzi Zhang, Stanford University, Stanford, CA, 94305, United States

- 1 - Predicting Information Diffusion Probabilities in Social Networks Based on Neural Networks**

Zhecheng Qiang, PhD Student, University of Central Florida, 4000 Central Florida Blvd., Orlando, FL, 32826, United States, Alexander Semenov, Qipeng Zheng

Predicting information diffusion through social networks plays an important role in human activities analysis and influence maximization realization. Our paper focuses on predicting information diffusion probability in social networks based on artificial neural networks. In this paper, we analyze and study the fundamental factors that might affect the diffusion process. Then we implement deep neural network and generalized regression neural network to predict the diffusion probability. We evaluate our models on several real data sets and it shows our models are effective and outperform the state-of-the-art methods.

- 2 - Multiple Instance Learning via Quadratic Programming**

Emel Seyma Kucukasci, Istanbul Commerce University, Kucukyali E5 Kavasi Inonu Cad No 4, Istanbul, 34840, Turkey, Emel Seyma Kucukasci, Bogazici University, Istanbul, Turkey, Mustafa Gokce Baydogan, Z. Caner Taskin

In multiple instance learning (MIL), objects are represented by a bag of instances and the class labels are known for the bags, but not for the individual instances.

We present a novel quadratic programming-based approach to classify bags. Our algorithm imposes no additional constraints on relating instance labels to bag labels and applicable to many learning problems such as image classification, molecule activity prediction and text mining. We demonstrate the computational efficacy and classification success of our approach on a wide range of real world datasets.

- 3 - Features Level Opinion Mining from Informal Text Corpus Using Machine Learning Techniques**

Prabin Kumar Panigrahi, Indian Institute of Management Indore, Rau-Pithampur Road, Indore, 453556, India, Nishikant Bele

Due to Internet, torrent amount of informal text is generated. People express their views, emotion, feeling, and opinion on blogs, reviews, and social sites. This paper explores the use of machine learning technique at feature level sentiment categorization of Hindi blogs reviews at unigram, bigram, trigram and n gram level. We used six types of machine learning techniques to study whether unigram, bigram, trigram, and n-gram can be used for sentiment mining at the feature level. Our study shows that bi-gram with SVM outperformed the other methods.

- 4 - Robust Bayesian Level Set Estimation via Gaussian Processes**

Junzi Zhang, Stanford University, Palo Alto, CA, 94304, United States, Andrea Zanette, Mykel John Kochenderfer

This paper focuses on the problem of determining as large a region as possible where a function exceeds a given threshold with high probability. We assume that we only have access to a noise-corrupted version of the function and that function evaluations are costly. To select the next query point, we propose maximizing the expected area of the domain identified as above the threshold as predicted by a Gaussian process, robustified by a variance term. We also give asymptotic guarantees on the exploration effect of the algorithm, regardless of the prior misspecification. We show by various numerical examples that our approach also outperforms existing techniques in the literature in practice.

## ■ TE66

West Bldg 105A

**Joint Session DM/Practice Curated: Intriguing Tweaks in Data Science II**

Sponsored: Data Mining

Sponsored Session

Chair: Derya Dinler, Middle East Technical University, ODTU Endystri Myhendisligi, Ankara, Turkey 06800

- 1 - Sparse Component Analysis of Locally Dominant Source**

Syed Mujahid, Asst. Professor, KFUPM, Dhahran, Saudi Arabia

In this talk, the linear case of Blind Signal Separation (BSS) problem is presented. Conventionally, the BSS problem is solved via the Independent Component Analysis (ICA) methods, which requires the statistically independence assumption. A different class of methods that are based on the notion of sparsity, are called as Sparse Component Analysis (SCA) methods. A novel LP model that can solve a specific class of SCA problems will be presented in this talk. Numerical results will be presented to illustrate the usability of the proposed model.

- 2 - Laplacian Regularized Gaussian Processes for Modeling Expensive Black-Box Functions**

Rajitha Meka, University of Texas-San Antonio, One UTSA Circle, San Antonio, TX, 78256, United States, Adel Alaeddini

In an increasing number of cases involving estimation of complex functions in the real world, one is often confronted with situations where there are several factors to be evaluated but experiments are prohibitively complex and/or expensive. Gaussian process (GP) is a well-known non-parametric regression method to fit nonlinear functions. We propose Laplacian regularized Gaussian processes with bilateral kernel to make use of both measured and unmeasured points for efficient modeling of expensive black-box functions.

- 3 - Probabilistic Distance Clustering on Networks**

Cem Iyigun, Associate Professor, Middle East Technical University, Inonu Blvd, Endustri Myhendisligi, Ankara, 06800, Turkey, Derya Ipek Eroglu

In this study, a soft clustering problem on networks is investigated. It is assumed that cluster centers are located not only on vertices, but also on the edges of the network. Two different soft assignment schemes are studied where different membership functions are considered for the assignments. Structural properties for the clustering problem have been derived for different problem settings and the relation to the p-median problem has been shown under specific conditions. As a solution approach, a metaheuristic algorithm using the properties of the problem has been proposed. Computational experiments have been conducted with different problem instances.

**4 - Tree-structured Data Clustering**

Derya Dinler, Middle East Technical University, ODTU Endustri  
Muhendisligi Bolumu, Cankaya, Ankara, 06800,  
Mustafa Kemal Tural, Nur Evim Ozdemirel

We consider a clustering problem in which data objects are rooted trees with unweighted or weighted edges and propose a k-means based algorithm which repeats assignment and update steps until convergence. The assignment step utilizes Vertex Edge Overlap to assign each data object to the most similar centroid. In the update step, each centroid is updated by considering the data objects assigned to it. For the unweighted edges case, we propose a Nonlinear Integer Programming (NIP) formulation to find the centroid of a given cluster and solve the formulation to optimality with a heuristic. When edges are weighted, we also provide an NIP formulation for which we have a heuristic not guaranteeing optimality.

**TE68**

West Bldg 105C

**Joint Session QSR/Practice Curated:  
Spatio-Temporal Data Analysis and Applications II**

Sponsored: Quality, Statistics and Reliability

Sponsored Session

Chair: Shyam Ranganathan

Co-Chair: Asif Sikandar Iquebal, MS, Texas A&M University, TX,  
United States

**1 - Optimal Sentinel Placement on a Network to Infer Transmission  
Probability of a Contagion**

Samarth Swarup, PhD, Virginia Polytechnic Institute and State  
University, Blacksburg, VA, 24060, United States, Yihui Ren,  
Stephen Eubank

We study the problem of optimal sentinel placement on a network to estimate the probability of transmission of a contagion. We assume that only one partial observation of the outbreak is available, corresponding to locations (nodes) where sentinels are placed. The problem is to choose the sentinel locations, given the graph and source node. Our approach relies on the mathematical theory of network reliability, which can be used to estimate the probability distribution of the transmission rate given a partial observation and the network structure. We cast the problem in an entropy maximization setting and develop a greedy approach for sentinel placement. Results on two real-world networks are shown.

**2 - Planar Random Graph Representations of Spatio-temporal  
Evolution of Surface Morphology**

Ashif S. Iquebal, Texas A&M University, College Station, TX,  
77840, United States, Satish Bukkapatnam, Soundar Kumara

We present a random planar graph representation to quantify the spatiotemporal evolution of surface morphology during finishing processes. We show that the proposed representation captures the complex interflow among neighboring asperities during finishing, and establishes an efficient endpoint criterion, i.e., surface quality improves only until each asperity interflows with six neighbors.

**3 - A New Nonhomogenous Poisson Process Model for  
Spatiotemporal Event Data**

Yifei Yuan, University of Arizona, 651 E. Camino Lujosa, Tucson,  
AZ, 85704, United States, Yinwei Zhang, Jian Liu

Spatially distributed events occurred over time are usually modeled by spatiotemporal point processes with nonstationary occurrence rate. Conventional methods based on prespecified B splines may not be accurate if the knot locations are not properly defined. A free knot B spline approach is proposed to optimally model the spatiotemporally dependent occurrence rate, with the knot locations and spline coefficients estimated simultaneously. A real-world case study demonstrates the effectiveness of the proposed method.

**4 - Numerical Simulation of the Conduction and Propagation of  
Spatiotemporal Electrodynamics in Complex Systems**

Bing Yao, The Pennsylvania State University, 801 B6 Southgate Dr,  
University Park, PA, 16801, United States, Hui Yang

Heart disease is a major threat to human health. The key to improving the cardiac care services is to develop a better understanding of cardiac activity. Computer simulations facilitate quantitative elucidation of heart functions. Here, we propose a novel method to simulate cardiac spatiotemporal electrodynamics. We project the 3D heart into a 2D graph by the method of t-distributed stochastic neighbor embedding. Then, a moving-least-square mesh-free method is proposed to simulate the nonlinear electrodynamics on the 2D graph. Simulation results show that this model efficiently simulates the cardiac electrodynamics, and will be an effective tool for optimal medical decision-making.

**5 - An Adaptive Approach for Fusion of High-accuracy with  
Low-accuracy Data**

Mostafa Reisi Gahrooei, PhD, Georgia Institute of Technology ,  
GA, United States

Available data fusion techniques concentrate only on data fusion strategies without providing guidelines on how to sample high-accuracy (HA) data. This work addresses the problem of selecting HA data adaptively and sequentially so when it is integrated with the low-accuracy (LA) data a more accurate surrogate model is achieved.

**TE69**

West Bldg 106A

**Spatio-temporal Modeling and Analysis**

Sponsored: Quality, Statistics and Reliability

Sponsored Session

Chair: Aziz Ahmed

Co-Chair: Yu Ding, Texas A&M University, College Station, TX,  
77843-3131, United States

**1 - Statistical Modeling of Spatio-temporal Data Arising from  
Stochastic Convection-diffusion Processes**

Xiao Liu, University of Arkansas

This talk will describe a holistic spatio-temporal modeling and analysis framework for large-scale spatio-temporal data sets arising from a broad class of physical convection-diffusion processes.

**2 - Spatio-temporal Modeling of Adverse Birth Outcomes Due to  
Heat Effects**

Shyam Ranganathan, Virginia Polytechnic Institute and State  
University, VT, Blacksburg, VA, United States, Christopher Grubb,  
Samarth Swarup, Julia Gohlke, Yuhao Wu

Observational studies to estimate effects that are rare in the population often report small effect sizes. Spatio-temporal models with random effects and spatial clustering can help improve estimates by disentangling confounders. We develop a novel spatio-temporal model and address an important problem in health effects of heat waves. Adverse birth outcomes such as low birth weight and preterm birth due to heat effects have been studied for some time. We use anonymized birth records data from Virginia to present our results for this problem using our model.

**3 - Combining Constrained Bayesian Optimization And Spatio-  
temporal Surveillance For Optimal Water Quality Monitoring  
Network Design**

Junzhuo Chen, Georgia Institute of Technology, Atlanta, GA,  
30318, United States

The goal of designing an optimal water quality monitoring network for river systems is to identify the location of a finite number of sensors that minimizes the expected detection delay of a contaminant event. In practice, data collected by sensors are subject to measurement errors, which makes a statistical procedure necessary to control the false alarm rates when using such streaming data for contaminant detection. We propose a combined framework of Spatio-Temporal surveillance and Bayesian Optimization for robust sensor network design in the presence of sensor measurement error.

**4 - Spatio-temporal Modeling & Analysis For Wind Farm Data.**

Ahmed Aziz, Texas A&M University, 2500 Central Park Ln Unit  
2406, College Station, TX, 77840, United States

Wind data are known to exhibit dependencies across a broad spectrum of spatial and temporal scales. In this talk, we present several findings related to the spatio-temporal modeling and analysis of local wind dynamics using turbine-specific wind farm data. We discuss various concepts such as space-time interaction, flow-dependent asymmetry and regime-switching dynamics, and present novel ways to incorporate them into spatio-temporal models. Finally, we discuss the implications of such findings on the wind farm operational analytics such as wind speed forecasting and power estimation.

**5 - Spatiotemporal Transfer Learning for 3D Dynamic Field Modeling**

Di Wang, Peking University, Beijing, China, Xi Zhang

We propose a 3D field estimation method using limited sensor observations. A dynamic field transfer learning approach, to identify spatiotemporal correlation by integrating a multitask learning framework into an autoregressive model, is developed. Our proposed approach is verified through a real case study of grain thermal field estimation.



## ■ TE70

West Bldg 106B

**Joint Session DEA/Practice Curated: Applications III**

Emerging Topic: Productivity, Efficiency and Data Envelopment Analysis

Emerging Topic Session

Chair: Xiang Ji, University of Science and Technology of China, 800 W Renner Road, Richardson, TX, 75080, United States

**1 - A Heterogeneous DEA-based Eco-efficiency Measurement of China's Industrial Sectors**

Mingjun Li, University of Science and Technology of China, Hefei, China, Jie Wu

Environmental problems brought by industry are attracting extensive attention so a comprehensive analysis of industrial environmental performance is increasingly important. In this paper, we extend the DEA model to consider two-sided non-homogeneous problems, handling DMU sets that have non-homogeneity in both inputs and outputs. This is different from the previous researches which generally focus on regional data to avoid heterogeneity. With this more realistic analysis of environmental efficiency, the Chinese government can make more informed decisions to realize sustainable industrial development.

**2 - DEA Cross-efficiency Model with Reciprocal Behavior**

Feng Li, Southwestern University of Finance and Economics, Chengdu, 611130, China

A reciprocal behavior is responding much nicer to friendly actions and much nastier to hostile actions. This paper integrates the reciprocal behavior among Decision Making Units (DMUs) into Data Envelopment Analysis (DEA) cross-efficiency approaches. To this end, a series of games are developed by viewing each DMU as a player and adopting different evaluation strategies. Several equilibrium points are obtained for different strategies, and game theoretical implications are provided. Finally, the proposed approach is applied to logistics industries.

**3 - Using A Hybrid Heterogeneous DEA Method to Benchmark China's Sustainable Urbanization**

Xiang Ji, University of Science and Technology of China, 96 Jinzhai Rd, Hefei, 230026, China, Jie Wu, Qingyuan Zhu, Jiasen Sun

Due to recent official policy changes, China's sustainable urbanization has entered a new type of multi-target heterogeneous situation which has never been scientifically researched before. To deal with this new heterogeneous scenario, we introduce a hybrid heterogeneous data envelopment analysis (DEA) method that contains input segment estimation and efficient frontier construction. We also introduce a bi-level benchmarking method that benchmarks each city's eco-efficiency and uses those benchmarks to guide sustainable urbanization completion in an empirical study of 206 Chinese prefecture-level cities' sustainable urbanization.

## ■ TE71

West Bldg 106C

**Joint Session ICS/IOS Discreet: Advances and Applications in Multilevel Mixed-integer Optimization**

Sponsored: Computing

Sponsored Session

Chair: Leonardo Lozano, University of Cincinnati, Cincinnati, OH, 45219, United States

Co-Chair: Christopher Ryan, University of Chicago, Chicago, IL, 60637, United States

**1 - Robust Optimization with Mixed-integer Uncertainty Sets**

Juan Sebastian Borrero, Assistant Professor, Oklahoma State University, 322 Engineering North, Stillwater, OK, 74078, United States, Leonardo Lozano

We consider robust linear optimization problems where the uncertainty set is a mixed-integer linear feasibility region. Such a class of sets allows us to model complex uncertain phenomena where there are logical, combinatorial, or disjunctive relationships in the uncertain data. We show that optimizing over this type of sets greatly reduce the conservativeness of the optimal solutions when compared to a convex counterpart. However, the reduction comes at the price of increasing the computational complexity of the problem. In particular, the problem is NP-hard and we develop iterative solution methods based on decomposition techniques that solve many instances of the problem in a reasonable time.

**2 - The Watermelon Algorithm for The Bilevel Integer Linear Programming Problem**

Lizhi Wang, Iowa State University, IMSE and ECPE, Ames, IA, 50011, United States

We will review the watermelon algorithm for the bilevel integer linear programming problem and present an improved version of the algorithm that uses a number of techniques specifically designed for the bilevel structure of the problem to improve the efficiency of the algorithm.

**3 - Lagrangian Dual Decision Rules for Multistage Stochastic Integer Programming**

Merve Bodur, University of Toronto, 5 King's College Road, Toronto, ON, M5S 3G8, Canada, James Luedtke, Maryam Daryalal

We propose Lagrangian dual decision rules that yield a new approximation approach for multi-stage stochastic integer programming problems. We investigate techniques for using these decision rules to obtain bounds on the optimal value and a primal feasible policy; and compare the strength of the relaxation from different techniques. Numerical results will be presented to illustrate the quality of the obtained bounds and policies.

**4 - Representability and Solvability of Mixed-integer Bilevel Programming Problems**

Sriram Sankaranarayanan, Johns Hopkins University, Baltimore, MD, 21218, United States, Amitabh Basu, Christopher Ryan

We show that the feasible regions modeled by continuous bilevel constraints, complementarity constraints and polyhedral reverse convex constraints are the same. We show that their feasible regions model the finite union of polyhedra. We contrast it with the modeling power of mixed-integer problems that model finite union of polytopes along with an integer cone. Then we show that allowing both integer constraints and continuous bilevel constraints, one can model finite union of polyhedra and finite union of integer cones. Having said that, by fixing certain variables, we show non-emptiness of a relaxed mixed-integer bilevel set can be decided in polynomial time.

## ■ TE72

West Bldg 211A

**Practice- Operations Management I**

Contributed Session

Chair: Debdatta Sinha Roy, Robert H. Smith School of Business, University of Maryland, College Park, MD, 20742, United States

**1 - An Improved Quasi-experiment to Evaluate the Effectiveness of Performance-based Reward**

Lingfeng Li, Vanguard Group, Wayne, PA, United States

Performance-based reward (PBR) has been adopted to facilitate the achievement of organizational goals. However, evidence on the effectiveness of PBR is limited, and methods to evaluate PBR effectiveness have not been well established. This work is the first effort to introduce an improved quasi-experiment (IQE) to obtain high level of evidence to support decision-making on the application of a PBR. Our pilot results suggest the effectiveness of a PBR could vary across operational settings: PBR could improve the productivity of employees who process not-in-good-order items by at least 5% (p-value = 0.00005). However, evidence is insufficient for employees who process in-good-order items.

**2 - Portfolio Choice of Renewable Energy**

Chen Wei, University of Electronic Science and Technology of China, Chengdu, China, Ma YongKai, Tang Xiao Wo

Most countries used the Energy Internet, which has a key feature that the electricity is mainly generated by renewable energy, to reduce carbon emissions. Renewable energy (i.e., wind and solar) is volatility, however, renewable energy combination on-grid can reduce the renewable energy volatility. This paper focuses on the portfolio choice of renewable energy. We constructed a model that utility firms, including conventional and renewable energy firms, supply the electricity to the market, in different pricing policies. We find that flat pricing leads to a higher investment level for solar energy, meanwhile, peak pricing leads to invest more wind energy.

**3 - Sequencing Mixed Models on an Assembly Line with Variable Rate Launching and Open Stations**

Tobias Moench, WHU-Otto Beisheim School of Management, Vallendar, Germany, Arnd H. Huchzermeier

Introduction of new models on an assembly line pools demand risk, but also increases costs of idle time, utility work and space. Opening up station boundaries and introducing variable rate launching instead of a fixed tact time reduces all costs simultaneously. Moreover, the overall line length is reduced significantly.

#### 4 - Efficiency and Risk Trade-off in Security Screening Operations

Mehmet Aydemir, Carnegie Mellon University, 5000 Forbes Ave, Pennsylvania, Pittsburgh, PA, 15213, United States, Alexandre Jacquillat, Alan Scheller-Wolf

The management of screening systems involves a trade-off between efficiency and risk. We model a screening system with a range of screening options having different service and risk mitigation characteristics, in which the controller can dynamically select the screening option based on job-level risk profile information. We propose a multi-class Markov decision process model of the control of such a screening system as a function of observed queue length and risk profile information. We show that the optimal policy exhibits a threshold behavior. We extend this model to a setting where customers are strategic. We find conditions where slower screening policies lead to shorter queue lengths.

#### 5 - Data Driven Variability Analysis of Vehicle Routes

Debdatta Sinha Roy, Robert H. Smith School of Business, University of Maryland, 7699 Mowatt Lane, 3330 Van Munching Hall, College Park, MD, 20742, United States, Bruce L. Golden

Delivery and service companies need to send out multiple vehicles to deliver customer products and provide services to customers in a city every single day. These companies generate the vehicle routes using routing software and algorithms provided by third party clients. It is a matter of great importance to maintain the workload balance among the drivers of a company, i.e., the drivers should have similar route times (inclusive of the service times). Based on real route times generated using two different third party software on various street networks, we perform statistical analysis to understand and quantify the variability in the route times and, thereby, make recommendations to the companies.

### ■ TE73

West Bldg 211B

#### JFIG Panel Discussion: Getting Research Funding

Sponsored: Junior Faculty JFIG

Sponsored Session

Chair: Anahita Khojandi, University of Tennessee, Knoxville, TN, 37996, United States

Co-Chair: Ehsan Salari, Wichita State University, Wichita, KS, 67260, United States

#### JFIG Panel Discussion: Getting Research Funding

Ehsan Salari, Wichita State University, 120C Engineering Building, 1845 Fairmount St., Wichita, KS, 67260, United States

Panelists will share their experiences and insights on how to successfully secure funding from a broad array of funding agencies.

#### Panelists

Jim Ostrowski, University of Tennessee, 11421 Old Colony Pkwy, Knoxville, TN, 37934, United States

Javad Lavaei, University of California, Berkeley, 4141 Etcheverry Hall, Berkeley, CA, 94720, United States

Amir Ali Ahmadi, Princeton University, Dept. of Operations Research&Financial Eng., Sherrerd Hall (room 329), Charlton Street, Princeton, NJ, 08544, United States

### ■ TE74

West Bldg 212A

#### Preference-driven Decision Aiding II

Sponsored: Multiple Criteria Decision Making

Sponsored Session

Chair: Adiel Teixeira De Almeida Filho, Universidade Federal de Pernambuco, Recife-PE, 50.630-971, Brazil

Co-Chair: Roman Slowinski, Poznan University of Technology, 60-965, Poland

#### 1 - Resource Allocation with Fairness-based Preferences

Nikolaos Argyris, Loughborough University, School of Business and Economics, Loughborough University, Loughborough, LE11 3TU, United Kingdom

We consider the problem of a inequality-averse central planner distributing resources across different parties. Taking an axiomatic approach, we construct an "equitable preference ordering combining structural assumptions with preference information. We show that the set of functions that represent the preference

ordering has a succinct polyhedral characterization. We use this to compute the subset of "equitably-efficient" resource distributions. We show how these results can be used to introduce fairness constraints in optimization formulations of resource allocation problems (e.g. to stipulate that the optimal distribution must equitably-dominate a reference distribution).

#### 2 - Preference Driven Private Banking Decisions:

##### A Personal Investment Portfolio Optimization Framework

Adiel Teixeira De Almeida Filho, Universidade Federal de Pernambuco, Caixa Postal 7471, Cx Postal 7471, Av. General San Martin, 1083, Recife-PE, 50.630-971, Brazil, Drance Oliveira, Luciano Ferreira, Denis Borenstein, Marcelo Righi

Since the mean-variance approach, portfolio optimization has been developed and recent literature addresses two main streams: (i) the incorporation of alternative risk measures and (ii) the development of new models and innovative problem formulation to enable additional characteristics that the investor wish to consider or that financial services are obliged to comply due to regulation. This work focuses on the latter issue in portfolio modeling for private banking into a preference driven process by integrating throughout a decision process framework to support portfolio selection.

#### 3 - Evaluating Credit Risk of Brazilian Debentures Through a New Preference Disaggregation Approach

Diogo Ferreira de Lima Silva, MSc, Universidade Federal de Pernambuco, Recife-PE, 50630971, Brazil, Adiel Teixeira De Almeida Filho, Luciano Ferreira

Given the importance of credit risk evaluations for individual investors and financial agents, new approaches and models have been formulated over the years. In Brazil, sovereign and corporate bonds are among the leading investment alternatives. This work presents a preference disaggregation for sorting problems within the TOPSIS method. Using real data collected from public financial statements the proposed approach is used to evaluate these corporate bonds.

#### 4 - A Preference Driven Approach for Determining the Ideal Inspection Interval for a Runway with Delay Time Modeling

Naiara Meireles de Souza, Universidade Federal de Pernambuco, Recife, 50630971, Brazil, Marcelo Hazin Alencar, Adiel Teixeira De Almeida Filho

We sought to determine an inspection interval for an airport runway located in Northeast of Brazil through a maintenance and inspection policy based on Delay Time Modeling, considering cost and availability.

### ■ TE75

West Bldg 212B

#### Development, Acquisition, and Maintenance

Sponsored: Military and Security

Sponsored Session

Chair: Jesse Pietz, U.S. Air Force, 8991 Shadowlake Way, Springfield, VA, 22153, United States

#### 1 - Tradespace Analytics for Air Force Acquisition Programs

Jesse Pietz, U.S. Air Force, Washington, DC, United States

Each year the United States Air Force (USAF) must weigh multiple priorities in order to determine how to allocate its multibillion-dollar budget among thousands of major acquisition programs. This talk describes an analytical approach that combines an Analytic Hierarchy Process (AHP) and cost forecasting within a Monte Carlo sampling framework to generate a tradespace that allows decision makers to visualize and assess the marginal value of their program decisions, and explores the many modeling challenges that result.

#### 2 - Advances in Obsolescence Management Utilizing Reliability Theory

Christina Mastrangelo, University of Washington, 2319 44th Avenue SW, Seattle, WA, 98116, United States

Obsolescence issues grow as the lifecycles of most electronic parts decrease. This talk focuses on forecasting obsolescence for a DoD application and describes a method to accurately forecast the likelihood of lifecycle duration to support a proactive strategy to manage future obsolescence events. The basis is the calculation of corresponding probabilities of obsolescence for each part in a system via reliability theory and Bayesian calculations. This approach is extended by examining the shortening of product life cycles in conjunction with the shape of the product life cycle curve which leads to the prediction of obsolescence. The research presents an innovation in system level obsolescence.

### 3 - Column Generation Algorithm for Preventive Maintenance Scheduling with Hierarchical Set-ups

Yongpei Guan, University of Florida, 303 Weil Hall, P.O. Box 116595, Gainesville, FL, 32611, United States, Eric C. Blair

We study a preventive maintenance (PM) scheduling problem where there are multiple PM activities that must be completed within some time-variant cycle limit, along with a group of set-up activities which must be performed in conjunction with certain PM activities based on a tree-like dependency graph. The objective is to minimize total cost of performing set-up and PM activities over a finite horizon. Relaxing the dependency constraints, we show the problem with only cycle limit constraints has the integrality property. We develop a column generation framework with pricing problems solvable in polynomial time exploiting this structure, and show computational results of the approach.

## ■ TE76

West Bldg 212C

### Joint Session PSOR/MIF: Non-profit Operations in Humanitarian and Disaster Response Logistics

Sponsored: Minority Issues

Sponsored Session

Chair: Trilce Encarnacion, Rensselaer Polytechnic Institute, Troy, NY, 12180, United States

#### 1 - A Minimal Technology Routing System for Food Banks Mobile Food Pantry Programs

Eduardo Perez, Assistant Professor, Texas State University, Roy F. Mitte Complex, 749 N. Comanche St., San Marcos, TX, 78666, United States, Emilia Ochoa, Jesus Jimenez

The Mobile Pantry Program directly serves clients in areas of high need with the goal of supplementing other hunger-relief agencies. Through a Mobile Pantry, a truckload of food is distributed to clients in pre-packed boxes or through a market-style distribution where clients choose to take what they need. A novel routing system is developed to handle the daily routing of a limited number of vehicles serving varying number of delivery points. A case study is presented that shows how the new routing system can combine multiple visiting sites in one route to increase throughput rates.

#### 2 - Assessing Food Supply Chain Vulnerability Using Consumer Behavior and Mitigation/Compliance Strategies

Jessye Bemley Talley, Morgan State University, Baltimore, MD, 21251, United States

As the food supply chain continues to grow globally, it is important to have strategies (i.e. recall) and tools to keep products safe when purchased by the end consumer. However, the guidelines that indicate the best time to implement a recall is uncertain. It is also unclear on the best mode of messaging to communicate with consumers about these contamination events. An agent-based simulation approach is used to address the following: (1) consumer behavior, (2) messaging strategies, and (3) timing of mitigation strategies to reduce consumer illnesses.

#### 3 - Making Non-profit and Service-providing Agencies Smarter with Big Data Analytics

Charalampos Chelmiss, University at Albany, State University of New York, NY, United States, Daphney-Stavroula Zois, Wonhyung Lee

Currently, those in need of help often do not know how to locate or access service providers. Likewise, service-providing agencies often work in silos. Response becomes even more problematic when a problem demands the coordination of service providers, volunteers, and government structures, and after business hours, when the communication channels that can aid people in need become sparse. In this work, we report our ongoing project towards developing analytic solutions to help non-profit and community-based organizations respond effectively to the needs of their communities. We report our preliminary findings, and discuss key challenges and future plans.

#### 4 - Role of Non-established Groups in the Aftermath of Hurricanes Harvey, Irma, and Maria

Trilce Encarnacion, Rensselaer Polytechnic Institute, 110 8th Street, Jonsson Engineering Center # 4049, Troy, NY, 12180, United States, Jose Holguin-Veras, Diana Gineth Ramirez-Rios, Johanna Amaya

Research has already established that the civic society plays a major role in all aspects of the response to extreme events, from search and rescue and relief distribution, to rebuilding efforts. This paper presents preliminary findings of the role of civic society and other non-established groups in the disaster response efforts to Hurricanes Harvey, Irma, and Maria impacted the US and the Caribbean in 2017.

### 5 - Value Function Approximation for Last-mile Distribution in Humanitarian Relief

Robert Alexander Cook, University of Alabama, Northport, AL, 35473, United States, Emmett J. Lodree

This study describes a Value Function Approximation approach for solving a Markov Decision Problem in which we distribute stochastically-arriving donations to disaster survivors. Donations accumulate over time at collection sites and are periodically transported to a relief center where the donations are distributed to beneficiaries over a finite horizon.

## ■ TE77

West Bldg 213A

### Matching and Recommendation Systems with Social Impact

Sponsored: Public Sector OR

Sponsored Session

Chair: Tina Rezvani, Northeastern University, Boston, MA, 02115-4420, United States

Co-Chair: Ergun Ozlem

#### 1 - On-demand Volunteers Through a Hierarchical Approach with Personalized Recommendations and Choice

Jennifer A. Pazour, Rensselaer Polytechnic Institute, 110 8th Street, CII 5217, Troy, NY, 12180, United States, Seyed Shahab Mofidi

A new hierarchical approach enables on-demand volunteers by recasting the platform's role as one providing personalized recommendations (i.e., a menu of multiple requests) to ad hoc volunteers. Choice can increase participation (capacity) and resource utilization. A novel bilevel optimization framework captures the interdependent outcomes of volunteer selections. The computationally expensive mixed integer linear bilevel problem is transformed into a single level problem by proposing logical expressions. Insights on what influences the optimal number of choices and performance are explored.

#### 2 - Maintaining Diversity in Student Exchange

M. Utlu Unver, PhD, Boston College, Boston, MA, United States, Umut Dur

In Europe, annually 200,000 college students study in different countries through Erasmus Student Exchange. Although this exchange is successful in many dimensions, it has two major drawbacks. First, the number of students exchanged is not country-balanced. Unbalanced exchange causes a financial burden for countries that are importing more students than their exports. Second, certain countries are exchanging students mainly between each other, limiting diversity, one of the main goals of the exchange. We propose the diversity-motivated top-trading-cycles-and-chains mechanism to solve these problems by satisfying constrained efficiency, strategy-proofness, and fairness.

#### 3 - Centralized Mechanisms for Two-sided Stable Matching with Societal Impacts

Tina Rezvani, Boston, MA, United States

Agents often are not aware of all their options or making applications for all positions can be costly. We leverage the staff assignment problem in the World Food Programme where a perfect assignment of staff and job positions is required. Perfect matching under partial information is incompatible with ensuring stability. To address this issue, we design a multi-period mechanism that negotiates on behalf of self-interested agents and identifies an increased-cardinality matching that guarantees a minimum level of stability while maximizing social welfare for all agents across multiple periods.

#### 4 - Constructing Ordinal Preference Lists with Ties Using Spectral Clustering

Matthew Williams, Northeastern University, Boston, MA, United States

We study the matching of military cadets to assignments over two periods, modeling the problem as a weighted, rank-maximal capacitated house allocation problem with ties (CHAT). To ensure every instance of the problem admits an agent-complete matching, we propose obtaining agent-specified ranks of the categorical attributes of assignments. Using spectral clustering, with these weights as input, we construct complete ordinal preference lists, with ties, for each agent. Lastly, we propose a generalization of CHAT to include gender constraints for further study.



## ■ TE78

West Bldg 213B

### Alternative-Fuel Vehicles Refueling and Routing Problems III

Sponsored: Location Analysis

Sponsored Session

Chair: Ismail Capar, Texas A&M University, College Station, TX, 77843-3367, United States

Co-Chair: Yudai Honma, The University of Tokyo, Tokyo, 153-8505, Japan

#### 1 - Electric Vehicle Routing Problem with Time Windows and Ambient Temperature Effect

Bulent Catay, Prof., Sabanci University, Orhanli, Tuzla, Istanbul, 34956, Turkey, Rastani Sina, Yuksel Tugce

We extend the Electric Vehicle Routing Problem with Time Windows by taking into account the ambient temperature. We formulate this problem as a mixed integer linear program and propose a set of network reduction rules. We perform an extensive experimental study to investigate how ambient temperature influences the routing decisions and to analyze the contribution of the proposed rules to run time. We present managerial insights to both researchers and practitioners by solving small instances using a commercial solver. The results show the effectiveness of the reduction rules and reveal that neglecting temperature effect may yield route plans that cannot be implemented in the business environment.

#### 2 - A Continuous Location Problem – Locating Refueling Points on Lines and Comb Trees

Yazhu Song, Arizona State University, 699 S. Mill Avenue, BYENG 219, Tempe, AZ, 85281, United States, Pitu B. Mirchandani

There is much reason to believe that many individuals and organizations will transform their vehicles to ones that utilize more sustainable alternative fuels. Among all, the EV is a promising candidate for this transformation. Unfortunately, little effort has gone into designing the layout of the battery charging/swapping infrastructure. This presentation discusses a new set of continuous location problems related to locating refueling points (RPs) on real lines, trees and general networks. Minimization of the number of RPs used to refuel all O-D flows is considered as the first objective. Then the objective is to locate a fixed number of RPs to minimize the total weighted travel distance.

#### 3 - Capacity and Location Design of Charging Facilities for Private Electronic Vehicles

Ting Wu, Associate Professor, Nanjing University, Department of Mathematics, No 22 Hankou Road, Nanjing, 210093, China, Cheng Zhu

Electronic Vehicles (EV) tend to have significant impacts on the economy, environment and the society. This study tends to address the design of charging facilities for EVs via robust optimization and analytics. Specifically, we aim to answer the following research questions: 1) what charging approach(es) is optimal for a specific region? 2) Does charging at close stations or locations outside transportation network improve the efficiency of the network? 3) How should we determine the location(s) and capacity of the optimal charging approach(es)?

## ■ TE79

Hyatt, Curtis A

### Supply Chain Management V

Contributed Session

Chair: Rodrigo Ulloa, Arizona State University, Tempe, AZ, 85281, United States

#### 1 - Is Supplier-base Concentration Risky? Empirical Evidence from Small and Medium Sized Enterprises (SMES) of Manufacturing Sector in China

Feng Liu, Korea University Business School, Anam-ro 145, Seongbuk-gu,, Seoul, Korea, Republic of, Kwangtae Park

This study investigates whether and how supplier-base concentration affects the relationship of operational efficiency to performance and risk. We try to integrate inventory turnover with supplier-base concentration, firm performance and credit risk. The study shows that inventory turnover contributes positively to firm performance but supplier-base concentration has a negative impact on firm performance. Interestingly, supplier-base concentration negatively moderates the relationship between inventory turnover and firm performance. We also find that inventory turnover negatively affects credit risk and supplier-base concentration positively affects credit risk.

#### 2 - Outsourcing under Competition: When to Choose a Competitor as a Supplier?

Olga Perdikaki, University of South Carolina, Darla Moore School of Business, 1014 Greene Street, Columbia, SC, 29208, United States, H. Sebastian Heese, Eda Kemahlioglu Ziya

Motivated by several examples of sourcing from direct competitors in different industries, we study a stylized supply chain model with a single OEM that could outsource either to an independent supplier or to an integrated firm that carries out manufacturing in-house and competes with the OEM. We identify how the presence of scale economies and competition affects the OEM's supplier choice.

#### 3 - A Stochastic Framework for Designing Complementary Agricultural Supply Chains

Rodrigo Ulloa, Arizona State University, 513W 17th St, Tempe, AZ, 85281, United States, Hector Flores, J. Rene Villalobos

We present an integrated planning framework that allows the insertion of independent farmers into commercial agricultural supply chains. In particular, we discuss the design and planning aspects of agri-food supply chains that can attain profitability through the utilization of stochastic optimization. The output from this framework is a planting and harvesting schedule for identified regions along their assigned consumer market. The framework also helps identify geographical regions with hidden agricultural potential given by their geographical location and weather patterns, where a two-stage stochastic program is developed to address the stochasticity of the weather.

## ■ TE80

Hyatt, Curtis B

### Practice- Supply Chain Management II

Contributed Session

Chair: Mengke Tian, The Hong Kong University of Science, Room 3208, Dep. of IEDA, Acade, Hong Kong

#### 1 - Impact of Supplier's Lead Time on Assembler's Strategic Decisions

Yuhong He, Assistant Professor, California State University-Fullerton, 2550 Nutwood Avenue, SGMH 4149, Fullerton, CA, 92831, United States, Wenting Pan

This paper examines the impact the supplier's lead time has on the assembler's strategic choice of partnership. Specifically, we study when the assembler would buy components from the suppliers and when the assembler would have a vendor-managed consignment contract with the suppliers. Furthermore, we also explore the conditions under which a supplier would be selected by the assembler as a sub-assembler to manage other suppliers.

#### 2 - Partial Vertical Integration in Supply Chains

Yibin Zhang, Associate Professor, Lixin University of Accounting & Finance, 2800 Wenxiang Road, Songjiang University Town, Shanghai, 201620, China, Xiaoguang Wang, Victor Shi

It is widely assumed in the operations management literature that vertical integration can eliminate double marginalization and boost supply chain efficiency. However, a number of research studies find that full disintegration can be beneficial in certain strategic context. In this paper, motivated by the common business phenomenon that firms hold each other's ownership shares, we study partial vertical integration in supply chains. Our findings show that partial vertical integration can be the equilibrium channel structure in supply chains. Hence, our research provides another important justification for the business practice of partial ownership among firms.

#### 3 - A Supply Chain Framework to Improve Survival and Productivity of Small Firms in Developing Countries: A Case Study in Latin America

Cansu Tayaksi, Postdoctoral Associate, Massachusetts Institute of Technology, 77 Massachusetts Ave, Cambridge, MA, 02139, United States, Josue Velazquez Martinez, Ramon Paulino, Rafaela Pereira Nunes

Small firms represent more than 95% of the companies in developing countries. Due to a lack of productivity, only a fraction survives. In this paper, we study the impact of SC practices in small firms and show that by improving SC expertise, small firms also improve their survival rate. We present a conceptual framework based on a system dynamics model that provides guidance on how small firms can focus on SC and business priorities. We validate our framework via a field study conducted in 50 companies in three countries in Latin America.

#### 4 - Product Line Planning Under Uncertainty

Sakir Karakaya, Industry and Technology Expert, Ministry of Science, Industry and Technology, Mustafa Kemal Mah.  
Eskisehir Yolu 7.km, Ankara, 06510, Turkey, Gulser Koksak

This study addresses the problem of multi-period mix of product-lines under a product family, which incorporates launching decisions of new products, capacity planning decisions and product interdependencies. The problem is modelled as a two-stage stochastic program in which price, demand, production cost and cannibalisation effect of new products are characterised as uncertain parameters. The solution approach employs the Monte Carlo bounding technique and L-shaped method, which is tested on real-like cases considering VSS and EVPI performance measures. The data collected through two experimental studies is analysed using ANOVA and Random Forest methodology.

#### 5 - A Comparison of Stochastic Service Model and Guaranteed Service Model in Multi-echelon Inventory Systems

Yinan Liu, Lehigh University, Philadelphia, PA, 19144, United States

The Stochastic Service Model (SSM) and Guaranteed Service Model (GSM) are competing models for optimizing multi-echelon inventory systems. SSM accounts for the uncertainty in lead times due to stockouts, while GSM treats lead times as bounded. SSM is more representative of real-world supply chains, but GSM is more tractable and widely used in practice. Our research asks whether GSM is an effective heuristic for SSM. Our results suggest that SSM and GSM agree closely in serial and assembly systems under many conditions. However, the two models often diverge for distribution systems, making GSM more problematic for more complex topologies.

#### 6 - How Does Conspicuous Consumption Affect Product Line Design

Mengke Tian, the Hong Kong University of Science and Technology, Hong Kong, Ying-Ju Chen, Xin Wang

We analyze the effects of conspicuous consumption on the product line design when there is only a monopoly manufacturer who tends to directly serve the market with high and low-end products. We find that stronger conspicuous effect undercuts the quality and prices for both products which leads to the increase of demands. The total profit of the manufacturer is elevated. The gaps of quality standard and selling price are widened. We extend by adding a retailer in the distribution channel. We find that manufacturer adopts the same quality strategies as before. The double marginalization effect leads to higher prices and lower demands. But its influence is mitigated when conspicuous consumption is stronger.

## ■ TE81

Hyatt, Phoenix East

### Robust Optimization

Contributed Session

Chair: Duaa Serhan, Binghamton University, Binghamton, NY, United States

#### 1 - From Data to Multi-stage Decisions

Bradley E. Sturt, Massachusetts Institute of Technology, Cambridge, MA, 02139, United States, Dimitris Bertsimas, Shimrit Shtern

In this talk, we consider multi-stage linear optimization problems, where the uncertainty is correlated between stages and our only information comes from historical data. We propose a simple data-driven framework, which we refer to as “sample robust optimization” (SRO). First, we establish that, as more historical data is obtained, SRO prescribes decision rules with (asymptotically) optimal out-of-sample performance. Second, exploiting structural similarities between SRO and robust optimization, we present practically-tractable approaches for solving SRO problems. Finally, we discuss empirical experiments and compare to approaches from distributionally robust optimization.

#### 2 - Optimization Over Continuous and Multi-dimensional Decisions with Observational Data

Christopher G. McCord, Massachusetts Institute of Technology, 77 Massachusetts Ave, Cambridge, MA, United States, Dimitris Bertsimas

We consider optimization under uncertainty over continuous and multi-dimensional decision spaces in problems in which we are only provided with observational data. We propose a novel algorithmic framework that is tractable, asymptotically consistent, and superior to comparable methods on example problems. Our approach leverages highly effective predictive machine learning methods for the purpose of prescribing decisions. We demonstrate the efficacy of our method on examples involving both synthetic and real data sets.

#### 3 - A Nested Robustness Approach for the Mobile Vendor Location Problem

Juan Carlos Espinoza Garcia, Assistant Professor, Tecnológico de Monterrey, Queretaro, 76130, Mexico, Laurent Alfandari

We propose an operational-level variant of the Capacitated Facility Location Problem applicable to mobile vendors, where the demand to each potential

location is a function of the selected locations. For this problem (MVLN) the demands follow a Poisson process, which provides fractional functions in the objective of the robust model when considering uncertainty on demands. We introduce the concept of Nested Uncertainty Budgets to address overly conservative solutions and propose a method to manage global and local uncertainty in a hierarchical way. Numerical experiments are provided on adapted benchmark instances to assess the performance of the nested robust model and a classical approach.

#### 4 - Robust Optimization for Routing and Scheduling of Airport Surface and Terminal Airspace Operations under Pushback and Arrival Times Uncertainty

Duaa Serhan, Binghamton University, Binghamton, NY, 13902, United States, Sang Won Yoon

This research proposed robust optimization approach for scheduling and routing airport surface and terminal airspace (ASTA) operations under uncertain flight schedules. Convective weather is the leading cause of flight delay in the National Airspace System. This paper aims to develop a decision support tool for routing and scheduling of ASTA operations during convective weather and different levels of aircraft pushback and arrival time uncertainty. A robust optimization approach is proposed to identify aircraft routes and schedules that minimize flight delays and safely avoid areas of convective weather. The proposed approach is expected to safely and efficiently manage aircraft operations.

#### 5 - An Economic Model Explaining Asymmetric Price Responses

Dong Soo Kim, Assistant Professor of Marketing, Ohio State University, 500 Fisher Hall, 2100 Neil Ave., Columbus, OH, 43210, United States, Mingyu Joo, Greg Allenby

This paper proposes a model that considers both expectation and uncertainty of information that formulates reference points as a distribution of outside option prices in a utility maximization framework. The model assumes that consumers compare the expected maximum attainable utility of outside options with the marginal utility from inside goods with observed prices. In doing so, the model characterizes the opportunity cost as a certainty-equivalent value, a value-adjusted standard to compare against. It shows that reference prices operationalized as point estimates in the literature may over-estimate the actual subjective standard, leading to asymmetric gain and loss parameter estimates.

## ■ TE82

Hyatt, Phoenix West

### Health Care V

Contributed Session

Chair: Stephen J. Stoyan, Abbott Laboratories, 100 Abbott Park Road, Chicago, IL, 60064, United States

#### 1 - A Dynamic Decision Framework of Vaccine Distribution for Influenza Interventions

Lo-Min Su, National Chiao Tung University, Hsinchu, Taiwan, Yu-Hsuan Wu, Sheng-I Chen

This study emphasizes on the vaccine distribution decision for national immunization programs with the consideration of uncertain epidemic pattern. We integrate disease and supply chain models, where a compartmental model is developed to provide the estimations of transmission intensity and population settlements, and a mixed-integer programming model to determine vaccine allocation according to the epidemic result at each stage. A forecast model of vaccine demand is also developed to acquire the demand for the integration model. We investigate the effectiveness of centralized and decentralized vaccine inventory policies under irregular pandemic and regular epidemic.

#### 2 - Grounding Frequent Flyers: Examining Utilization under the Patient Protection and Affordable Care Act

Eric Xu, University of Minnesota, Minneapolis, MN, United States

With the passage of the Patient Protection and Affordable Care Act, policy makers assumed that insurance coverage would encourage individuals to use primary care instead of emergency department care. One of the key tools to achieve this goal was Medicaid Expansion, which provided coverage to most vulnerable populations. However, under Medicaid Expansion, it appears that the utilization of ED and primary care services is rising. This research seeks to understand how the policy has impacted care delivery and utilization, in addition to capacity planning initiatives moving forward.

#### 3 - The Effect of Lifestyle Choices on Cancer: Which One has the Strongest Influence?

Banafsheh Behzad, California State University, Long Beach, CA, United States

Cancer is known to be caused by both genetic and environmental factors, with 80% of cancers being related to environmental factors. This shows the significance of our lifestyle choices in preventing cancer. The main lifestyle choices that affect the occurrence and mortality of cancer, analyzed in this study, are alcohol consumption, lack of physical activity, obesity, and tobacco usage. The strength of the association between cancer and these lifestyle choices are studied. The results show that the most influential lifestyle choices in predicting cancer are alcohol consumption and obesity.

#### 4 - An Alternative Method for Measuring Performance Outcomes of Hospital Acquired Infections

Christine Pitocco, Research Professor, Stony Brook University, 333 Harriman Hall, Stony Brook, NY, 11794, United States, Herbert F. Lewis, Jonathan Liu

Many hospital acquired infections (HAI) are preventable however it is estimated 2 million patients will acquire one. In this paper, we utilize NYS health data to measure the performance of hospitals in four categories of HAIs. We demonstrate the current method used by NYS is flawed and we propose an alternative method based on standard statistical methods.

#### 5 - Characterizing Obstructive Sleep Apnea with Association Rule Mining and Sequence Analysis

Rupesh Agrawal, Research Assistant, Oklahoma State University, Tulsa, OK, 74136, United States, Dursun Delen, Bruce Benjamin

A healthy individual goes through five stages of sleep in one standard sequence from wake (W) stage to rapid eye movement (REM) stage and three non-REM stages (NREM1, NREM2, NREM3). Obstructive sleep apnea (OSA) is highly correlated with several life-changing health manifestations such as atrial fibrillation, obesity, hypertension, etc. Pathological changes due to OSA and the severity of OSA (mild, moderate & severe) cause disturbances to the sleep pattern transition from one stage to another. This study aims to use association mining and sequence analysis to discover underlying patterns in sleep stage transitions.

#### 6 - Advanced Analytics in Healthcare

Stephen J. Stoyan, Director, Business Analytics & Strategy, Abbott, 100 Abbott Park Road, Chicago, IL, 60064, United States

Digital platforms, global demands, and customers have evolved in today's healthcare industry, where innovation, connecting with customers, and servicing the supply chain require higher levels of precision and execution. Abbott is a global leader in healthcare and advanced analytics is becoming an integral part of business operations and sales effectiveness. We present analytically tuned tools that are providing information that discover new opportunities, allow for better predictions, and provide business value.

### ■ TE83

Hyatt, Remington

#### Practice- Health Care V

Contributed Session

Chair: Jens Brunner, University of Augsburg, Universitätsstraße 16, Faculty of Business and Economics, Augsburg, 86159, Germany

#### 1 - Master Surgical Scheduling and Elective Surgeries Scheduling

M'Hallah Rym, Professor, Kuwait University, P.O. Box 5969, Safat, Kuwait, 13060, Kuwait

This paper proposes a stochastic model that determines a two-week master surgical schedule for a leading hospital. It determines the optimal expected number of surgeries per surgery type to plan for every two-week planning horizon. The model accounts for the random duration of both surgery times and post-surgery length of stays and the availability of post-surgery beds. It maximizes the expected operating theater's throughput. The model is solved via a sample average approximation with ranking and selection. Its application illustrates the potential savings it induces, the results' sensitivity to the length of the planning horizon and to the pooling of post-surgery beds.

#### 2 - A Two Stage Stochastic Mixed Integer Programming Approach for Short Term Nurse Schedule Adjustments

Osman Tuncay Aydas, Assistant Professor of Supply Chain Management, Oakland University, 275 Varner Drive, Elliot Hall 308, Rochester, MI, 48309, United States, Anthony Ross, Buket Aydas

We study short-term staffing adjustments of nurse schedules for the upcoming 4-hour shift. Developed two-stage stochastic programming model minimizes total nurse staffing costs, and the cost of adjustments to the original schedules developed in the medium-term planning phase, while ensuring adequate coverage of nursing demand. Our findings indicate, short-term stochastic schedule adjustments can deliver cost savings of up to 20%. As the number of unscheduled admissions increase there is a greater need for scheduling flexibility. We demonstrate the significance of part-time nurses, which alleviate under- and over-staffing risks and provide scheduling flexibility to the nurse managers.

#### 3 - Differentiating the Types of Inter-hospital Transfer Helps Hospital Choice Decisions

Lei (Raymond) Fan, Student, University of Houston, 4800 Calhoun Rd, Houston, TX, 77004, United States, Ming Zhao, Xiaosong David Peng

Inter-hospital patient transfer adds complexity to healthcare operations. We study inter-hospital transfers at the patient level. We develop a methodology to classify the transfers, and for each transfer type, we investigate the effects of transfer decisions on patient care performance. The results may be used by healthcare providers to develop better inter-hospital transfer guidelines.

#### 4 - Does Announcing the Visit Matter? An Empirical Examination in US Nursing Homes

Sehwon Kang, PhD Student, University of Minnesota, Carlson School of Management, Minneapolis, MN, 55455, United States, Rachna Shah, Kevin Linderman

Recently, healthcare accrediting agencies changed their on-site accreditation survey visits from announced to unannounced. In this study, using panel data from more than 3,000 US nursing homes over 4 years, we empirically examine the impact of this two regimes in terms of improving and sustaining quality performance.

#### 5 - Leveling of Intensive Care Unit Utilization by Efficient Surgery Scheduling

Jens Brunner, Prof. Dr., University of Augsburg, Universitätsstraße 16, Faculty of Business and Economics, Augsburg, 86159, Germany, Steffen Heider

The intensive care unit (ICU) is an expensive hospital resource serving both emergency and elective patients. The vast majority of ICU patients arrive from the operating theatre. In order to increase efficiency, we propose a mixed-integer programming model to optimize surgery scheduling with the goal of balancing the expected occupancy of patients in the ICU. The model is applied to two years of data from our cooperating hospital. We show that a more balanced utilization is possible without changing the master surgery schedule and that days without elective surgery have a negative effect when leveling the utilization at the ICU.

### ■ TE84

Hyatt, Russell

#### Practice- Disaster and Disruption Management I

Contributed Session

Chair: Duygu Pamukcu, Middle East Technical University, Ind., Ankara, 06400, Turkey

#### 1 - A Multistage Robust Model for Blood Transshipment Problem in Disasters

Jie Deng, Lecturer, Jiangnan University, School of Business, Jiangnan University, Wuxi, China

This research introduces a robust multi-echelon multi-stage model that can assist in blood transshipment problem with uncertain demand and supply in disasters, the proposed model considers service level-based policy in the blood scheduling process to minimize the unsatisfied demand and the time span between blood production in regional blood centers and consumption in demand zones for reducing blood shortage and wastage.

#### 2 - A Hypercube Queuing Equilibrium Approach to Dynamic Volunteer Firefighter Planning under Probabilistic Service Disruptions

Han Liu, University of Illinois, Urbana-Champaign, 722 Foley Ave, Champaign, IL, 61820, United States, CHAO LEI, Yanfeng Ouyang

We propose a multi-period hypercube queuing equilibrium model for the dynamic volunteer firefighter planning problem with multiple rescue rounds, with the consideration of that rescue services are under the risk of being disrupted. The applicability of the proposed model is tested on an empirical case study in Baoding. Numerical results show that more rescue resources should be dispatched in the first rescue round if the disaster deteriorates fast.

#### 3 - Minimization of the Social Impact of an Earthquake in Lima Metropolitana and Callao Optimizing the Speed of Response with Mathematical Models

Renzo Benavente, Pontificia Universidad Católica del Perú, Universitaria 1801, Lima, LIMA 32, Peru, Jonatán Edward Rojas Polo

This research shows opportunities for improvement in the response plan after an earthquake for the distribution of humanitarian aid. The proposed methodology begins with a clustering of the geographic area of Lima Metropolitana and Callao in 9 groups with a main warehouse in each. Then, the amount and location of temporary warehouses that will supply the affected population is calculated. Finally, a linear programming model is executed for the distribution of humanitarian aid goods from the central warehouse to the temporary ones. With this, it is possible to reduce the response time and make it more dynamic for the population.



#### 4 - Routing for Post-disaster Needs Assessment to Improve Information Accuracy and Precision

Duygu Pamukcu, Middle East Technical University, Middle East Technical Uni. Ind, Ankara, 06400, Turkey, Melih Celik, Burcu Balcik

Reliable information in the post-disaster needs assessment depends on how much time is spent for statistical sampling to collect information and how many different beneficiary groups visited. Estimated information is an input for relief distribution, so accuracy and precision of the estimation directly effect the efficiency of relief operations. The scarce resource, namely time, restricts visits to affected sites. Since information collection and travel time decisions are subject to the same total time constraint, there exists an inherent trade-off between them. Exact and heuristic methods are presented to analyze this tradeoff and support sample size and site selection decisions.

#### 5 - Multi-objective Robust Model of Stochastic and Possibilistic Programming for Mitigation Planning and Emergency Response

Luis Yáñez, Universidad de Chile, Santiago, Chile, Cristian Eduardo Cortes, Pablo Andres Rey

We propose a multi-objective robust model of stochastic and possibilistic programming for facility location, inventories allocation and distribution in the context of mitigation planning and emergency response. Our model seeks to optimize the risk associated with scenario planning and minimal total cost, including a social component, deprivation costs, faults of organization and convergence of materials. In addition, protection with respect to uncertain parameters is included in the model, as epistemic uncertainty given by the use of imprecise parameters and scarcely systematized information.

**Wednesday, 8:00AM - 9:30AM**

### ■ WA01

North Bldg 121A

#### Joint Session OPT/Practice Curated: Healthcare Operations under Uncertainty

Sponsored: Optimization/Optimization under Uncertainty

Sponsored Session

Chair: Yiling Zhang, University of Michigan, Ann Arbor, MI, 48105, United States

#### 1 - Appointment Scheduling under Time Dependent Patient No-Show Behavior

Zhenzhen Yan, Nanyang Technological University, 21 Nanyang Link, Singapore 637371, Qingxia Kong, Shan Li, Nan Liu, Chung-Piaw Teo

This paper studies how to schedule medical appointments with time-dependent patient no-show behavior and random service times. We observe a significant time-of-day effect on patient show-up probabilities from two clinic datasets. We deploy a distributionally robust approach to model the schedule problem. To tackle the case when patient no-shows are endogenous on the schedule, we construct a set of dual prices to guide the search for a good schedule and use the technique iteratively to obtain a near-optimal schedule. Our computational studies reveal a significant reduction in total expected cost by taking into account the time-of-day variation in show-up probabilities.

#### 2 - Hedging the Overtime Riskiness in Online Surgery Assignments

Minglong Zhou, National University of Singapore, Singapore, Melvyn Sim

We study an advanced scheduling problem where patients are assigned to different operating theatre slots. We propose an extended riskiness index as the risk measure. We show such riskiness index shares a representation in terms of a family of measures of risk. We further propose the lexicographical riskiness index, which defines a unifying framework to capture multi-priority or piece-wise preferences. We minimize the risk of failing to meet some targets in a forward looking framework with a non-anticipative policy to incorporate future uncertainty. Simulation results show that our approach controls the risk of overtime while not compromising overall number of surgeries compared to a Benchmark.

#### 3 - Nurse Staffing under Uncertain Demand and Absenteeism

Minseok Ryu, University of Michigan, 1911 McIntyre St, Ann Arbor, MI, 48105, United States, Ruiwei Jiang

This paper describes a data-driven approach for nurse staffing decision under uncertain demand and absenteeism. We propose a distributionally robust nurse staffing (DRNS) model with both exogenous (stemming from demand uncertainty) and endogenous uncertainty (stemming from nurse absenteeism).

We provide a separation approach to solve the DRNS model with general nurse pool structures. Also, we identify several classes of nurse pool structures that often arise in practice and show how the DRNS model in each of these structures can be reformulated as a monolithic mixed-integer linear program that facilitates off-the-shelf commercial software. Also, we propose an optimal nurse pool design model.

#### 4 - Integer Programming Approaches for Appointment Scheduling with Random No-shows and Service Durations

Yiling Zhang, University of Michigan, Ann Arbor, MI, 48105, United States, Ruiwei Jiang, Siqian Shen

We consider a single-server scheduling problem given a fixed sequence of appointment arrivals with random no-shows and service durations, of which only the support and first moments are known. We formulate a class of distributionally robust (DR) optimization models that incorporate the worst-case expectation/conditional Value-at-Risk (CVaR) penalty cost of appointment waiting, server idleness, and overtime as the objective or constraints. We obtain exact mixed-integer nonlinear programming reformulations and derive valid inequalities to strengthen the reformulations. Convex hulls are derived for the least and the most conservative supports of no-shows. Various instances are tested.

### ■ WA02

North Bldg 121B

#### Joint Session OPT/MIF: Multistage Mean-Risk Stochastic Programming

Sponsored: Optimization/Optimization under Uncertainty

Sponsored Session

Chair: Prasad Parab, Texas A&M University, College Station, TX, 77840, United States

#### 1 - Column Generation Algorithm for Risk-averse Two-stage Stochastic Programs

Saravanan Venkatachalam, Wayne State University, Detroit, MI, 48377, United States, Sujeevraja Sanjeevi

In the airlines operations, re-timing of flight legs is a tactic used in the schedules to minimize the cost of delay propagation. In this talk, we propose a two-stage mean-risk stochastic programming approach to determine the re-timing of flights and minimize the expected delay propagations due to disruptions on the day of operations. The mean-risk models pose computational challenges. In this talk, we present decomposition algorithms and computational results.

#### 2 - Decomposition for Risk-averse Multistage Stochastic Programs with Expected Conditional Risk Measures

Lewis Ntamo, Professor, Texas A&M University, 3131 TAMU, College Station, TX, 77843, United States, Maryam Khatami, Bernardo Pagnoncelli

We formulate risk-averse multistage stochastic programs (MSLPs) with expected conditional risk measures (ECRMs) in the context of both quantile and deviation mean-risk measures. We study decomposition algorithms for this class of problems. Using MSLPs with ECRM, we model and solve hydrothermal scheduling and lifetime portfolio selection problems. We investigate the impact of risk-aversion on decision making for these applications.

#### 3 - Stochastic Decomposition for Mean-risk Multistage Stochastic Linear Programs

Prasad Parab, Texas A&M University, College Station, TX, 77840, United States, Lewis Ntamo, Bernardo Kulnig Pagnoncelli

Mean-risk multistage stochastic linear programs (MR-SLPs) are difficult to solve due to the incorporation of risk measures in the objective function and their large-scale nature. In this talk, we present stochastic decomposition for MR-SLPs with deviation and quantile risk measures and report on its application to hydrothermal scheduling problems.

#### 4 - Multi-stage Risk-averse Stochastic Mixed-integer Programming for Mixed-model Assembly Line Sequencing

Ge Guo, Iowa State University, 4701 Todd Dr. Unit 208, Ames, IA, 50014, United States, Sarah M. Ryan

The existing optimization formulations for mixed-model assembly line sequencing do not consider some major real-world uncertainty factors such as timely part delivery and material quality. We present a multistage stochastic mixed-integer formulation to make sequencing decisions with optimal on-time performance considering uncertainties of part delivery and material quality. A risk-averse model is further developed to guarantee customers' satisfaction with on-time performance. Computational studies are performed with the Progressive Hedging algorithm and a lower bounding approach in real-time resequencing.

## ■ WA03

North Bldg 121C

### Stochastic and Robust Optimization

Sponsored: Optimization/Optimization under Uncertainty

Sponsored Session

Chair: Ruiwei Jiang, University of Michigan, Ann Arbor, MI, 48109, United States

#### 1 - Data-driven Chance Constrained Programs over Wasserstein Balls

Zhi Chen, Imperial College Business School, London, United Kingdom, Daniel Kuhn, Wolfram Wiesemann

We provide an exact deterministic reformulation for data-driven chance constrained programs over Wasserstein balls. For individual chance constraints as well as joint chance constraints with right-hand side uncertainty, our reformulation amounts to a mixed-integer conic program. In the special case of a Wasserstein ball with the 1-norm or the infinity norm, the chance constrained program can be reformulated as a mixed-integer linear program. Using our reformulation, we show that two popular approximation schemes based on the conditional-value-at-risk and the Bonferroni inequality can perform conservatively in practice and that these two schemes are generally incomparable with each other.

#### 2 - Exploiting Partial Correlations in Distributionally Robust Optimization

Karthik Murthy, Singapore University of Technology and Design, Singapore, Karthik Natarajan, Divya Padmanabhan

We aim to identify partial covariance structures that allow polynomial-time solvable tight reformulations for evaluating the worst-case expected value of mixed integer linear programs whose objective coefficients are uncertain. Assuming only the knowledge of the mean and covariance entries restricted to block-diagonal patterns, we develop a reduced SDP formulation whose complexity is characterized by a suitable projection of the convex hull of  $\{(1,x)'(1,x): x \in X\}$ , where  $X$  is the feasible region. These projected constraints lead to efficient characterizations for appointment scheduling problem, PERT networks, and linear assignment problems that are polynomial-time solvable.

#### 3 - The Discrete Moment Problem with Nonconvex Shape Constraints

Christopher Ryan, University of Chicago, 5807 S. Woodlawn Ave, Chicago, IL, 60637, United States, Xi Chen, Simai He, Bo Jiang, Teng Zhang

The discrete moment problem finds a worst-case discrete distribution that satisfies a given set of moments. We study the problem with additional “shape constraints that guarantee the worst case distribution is either log-concave or has an increasing failure rate. We characterize the structure of optimal extreme point distributions by developing new results in reverse convex optimization. We are able to show that an optimal extreme point solution to a moment problem with  $m$  moments and log-concave shape constraints is piecewise geometric with at most  $m$  pieces. This structure allows us to design an exact algorithm for computing optimal solutions in a low-dimensional space of parameters.

#### 4 - Distributionally Robust Combinatorial Optimization

Ruiwei Jiang, University of Michigan, 1205 Beal Ave., Ann Arbor, MI, 48109, United States, Shabbir Ahmed, Mohit Singh

We study distributionally robust analogs of combinatorial optimization problem with uncertain objective coefficients. We provide equivalent deterministic reformulations of such problems under several types of ambiguity sets, and discuss corresponding solution approaches.

## ■ WA04

North Bldg 122A

### Joint Session OPT/Practice Curated: Infinite Dimensional LP with Applications to Sphere Packing

Sponsored: Optimization/Integer and Discrete Optimization

Sponsored Session

Chair: Elahesadat Naghib, Princeton University, Princeton, NJ, United States

#### 1 - The Slater Conundrum: Duality and Pricing in Infinite-dimensional Optimization

Christopher Ryan, University of Chicago, 5807 S. Woodlawn Ave, Chicago, IL, 60637, United States, Kipp Martin, Matthew Stern

In finite dimensions, a dual solution is a vector of “dual prices that index the primal constraints and have a natural economic interpretation. In infinite dimensions, this structure may fail to hold for a broad class of problems with constraint vector spaces that are Riesz spaces that are  $s$ -order complete or satisfy the projection property. In these spaces, the existence of interior points required

by common constraint qualifications for zero duality gap imply the existence of singular dual solutions that are difficult to find and interpret. We call this the Slater conundrum. We provide sufficient conditions that guarantee that there exists an optimal dual solution that is not singular.

#### 2 - Linear Programming with Fourier Transform Constraints

Elahesadat Naghib, Princeton University, Princeton, NJ, United States, Robert J. Vanderbei

We exploit the special structure of Fourier Transforms that appear in certain linear optimizations to efficiently approximate their optimal solution. In many important instances of this family of problems such as upper-bounds on Sphere Packing, and Turan’s extremal problem, computational results can shed light and provide intuition about the form of solutions in these problems. Especially for higher geometrical dimensions that the computational efforts suffer from curse of dimensionality, and a theoretical understanding is very much lacking.

#### 3 - Bounding Infinite Dimensional LPs by Finite Dimensional LPs via Poisson Summation

Jacob Carruth, PhD, University of Texas at Austin, Austin, TX, United States

Optimization problems in which both a function and its Fourier transform are pointwise constrained by inequalities are common in applied and pure math problems. We demonstrate a technique which, if the problem has the right structure, allows one to bound the value of this infinite dimensional problem by the value of a finite dimensional linear programming problem. We’ll discuss applications of this technique to sphere packings and to the Beurling-Selberg box minorant problem.

## ■ WA05

North Bldg 122B

### Perturbation Analysis of Conic Optimization

Sponsored: Optimization/Linear and Conic Optimization

Sponsored Session

Chair: Ali Mohammad Nezhad, Lehigh University, Bethlehem, PA, 18015, United States

#### 1 - Parametric Analysis of Linear Conic Optimization

Ali Mohammad Nezhad, Lehigh University, Bethlehem, PA, 18015, United States, Tamas Terlaky

We consider the parametric and stability analysis of a linear conic optimization problem when the objective function is perturbed along a fixed direction. We study the continuity of the optimal set mapping and present the behavior of the so called optimal partition with respect to the perturbation of the objective vector. We estimate the length of a nonlinearity interval, where the dimension of the minimal faces containing the primal and dual optimal sets stays constant.

#### 2 - Condition Numbers for Convex Functions with Polytope Domains

David Gutman, Carnegie Mellon University, Pittsburgh, PA, United States, Javier Pena

We propose a condition number of a smooth convex function relative to a reference polytope. This relative condition number is defined as the ratio of a relative smooth constant to a relative strong convexity constant of the function, where both constants are relative to the reference polytope. The relative condition number extends the main properties of the traditional condition number. In particular, we show that the condition number of a quadratic convex function relative to a polytope is precisely the square of the diameter-to-facial-distance ratio of a scaled polytope for a canonical scaling induced by the function. Furthermore, we illustrate how the relative condition number of a function bounds the linear rate of convergence of first-order methods for minimization of the function over the polytope. In the final part of the talk, we will discuss possible extensions of the condition numbers to non-polytope domains.

#### 3 - On the Structure of the Inverse-feasible Region of a Linear Program

Onur Tavaslioglu, Research Assistant, University of Pittsburgh, 708 William Pitt Union, Pittsburgh, PA, 15260, United States, Taewoo Lee, Silviya Valeva, Andrew J. Schaefer

Given a set of feasible solution  $X$  to a linear program, we study the set of objectives that make  $X$  optimal, known as the inverse-feasible region. We show the relationship between the dimension of a face of a polyhedron and the dimension of the corresponding inverse-feasible region, which leads to necessary and sufficient conditions of the extreme, boundary, and inner points of a linear program. We also characterize the set of objectives that render a given solution uniquely optimal.

## ■ WA06

North Bldg 122C

**Journal of Global Optimization:  
INFORMS Issue Highlights**

Sponsored: Optimization/Global Optimization

Sponsored Session

Chair: Sergiy Butenko, Texas A&amp;M University, College Station, TX, 77843-3131, United States

**1 - On Branching-point Selection for Trilinear Monomials in Spatial Branch-and-bound: The Hull Relaxation**

Emily Speakman, Otto von Guericke University, Universitatplatz 2, IMO, G2-213, Magdeburg, 39106, Germany, Jon Lee

In Speakman and Lee (2017), we analytically developed the idea of using volume as a measure for comparing relaxations in the context of spatial branch-and-bound. Specifically, for trilinear monomials, we analytically compared the three possible “double-McCormick relaxations” with the tight convex-hull relaxation. Here, again using volume as a measure, for the convex-hull relaxation of trilinear monomials, we establish simple rules for determining the optimal branching variable and optimal branching point. Additionally, we compare our results with current software practice.

**2 - Unifying Local-global Type Properties in Vector Optimization**

Ovidiu Bagdasar, University of Derby, Derby, United Kingdom, Nicolae Popovici

It is well-known that all local minimum points of a semistrictly quasiconvex real-valued function are global minimum points. Also, any local maximum point of an explicitly quasiconvex real-valued function is a global minimum point, provided that it belongs to the intrinsic core of the function's domain. We have shown that these “local min - global min and “local max - global min type properties can be extended and unified by a general local-global extremality principle for generalized convex vector-valued functions with respect to two proper subsets of the outcome space.

**3 - A Simplicial Homology Algorithm for Lipschitz Optimisation**

Stefan Endres, University of Pretoria, Pretoria, South Africa, Carl Sandrock, Walter W. Focke

The simplicial homology global optimisation (SHGO) algorithm is a general purpose global optimisation algorithm based on applications of simplicial integral homology and combinatorial topology. SHGO approximates the homology groups of a complex built on a hypersurface homeomorphic to a complex on the objective function. This provides both approximations of locally convex subdomains in the search space through Sperner's lemma and a useful visual tool for characterising and efficiently solving higher dimensional black and grey box optimisation problems. The algorithm is specialised in finding all the local minima of an objective function with expensive function evaluations efficiently.

**4 - A Nonconvex Quadratic Optimization Approach to the Maximum Edge Weight Clique Problem**

Seyedmohammadhossein Hosseini, Texas A&amp;M University, College Station, TX, 77843-3131, United States, Dalila B.M.M. Fontes, Sergiy Butenko

Given an undirected and edge-weighted graph, the maximum edge weight clique (MEWC) problem is to find a subset of vertices inducing a complete subgraph with the maximum total sum of edge weights. We propose a quadratic optimization formulation for the MEWC problem and study characteristics of this formulation in terms of local and global optimality. In addition, we present an exact algorithm to solve the MEWC problem. The algorithm is a combinatorial branch-and-bound procedure that takes advantage of a new upper bound as well as an efficient construction heuristic based on the proposed quadratic formulation. Results of computational experiments on some benchmark instances are also presented.

**5 - Exploiting Algebraic Structure in the Belgian Chocolate Problem**

Zachary Burr Charles, University of Wisconsin, Madison, WI, United States

The Belgian chocolate problem involves maximizing a parameter  $\delta$  over a non-convex region of polynomials. Prior methods may require many iterations or find non-optimal  $\delta$ . We give a global optimization method that outperforms these methods by exploiting algebraic structure. This allows us to find large values of  $\delta$  via a simpler combinatorial optimization problem. Our approach leads to the largest known value of  $\delta$  to date,  $\delta = 0.9808348$ . We also show that in low degree settings, our method recovers previous known upper bounds on  $\delta$ .

## ■ WA07

North Bldg 123

**Social Networks and Algorithms**

Sponsored: Optimization/Network Optimization

Sponsored Session

Chair: Ali Rahim Taleqani, Upper Great Plains Transportation Institute, 310 East Bison Court, Fargo, ND, 58102, United States

**1 - Understanding the Positions, Activeness and Contributions in Online Task-oriented Community Network**Ruiyao Xie, Xi'an Jiaotong University, Xi'an, 710049, China  
City University of Hong Kong, Kowloon, Nam Shan Chuen Road, Nam Shan Building, Hong Kong, Qingpeng Zhang, Wentian Cui

Open source software community is a prominent case of online task-oriented community. We focused on the relationship between actors' positions in the network and contributions. Through the empirical study, we found that: Structural holes have the advantage in coding contributions. Brokerage of developers' positions is positively associated with coding contributions; Closure of positions is negatively associated with coding contributions; Developers' activeness moderates the relationship between closure positions and two types contributions. We analyzed time-lag effects of relationship between coding contribution and structural hole positions.

**2 - Applied Lagrangian Relaxed Linear Sum Assignment Problem in Social Networks Analysis**

Ivan Belik, Norwegian School of Economics, Helleveien 30, Bergen, 5045, Norway

We present a reformulation of the linear sum assignment problem (LSAP) and Lagrangian relaxation algorithm for the social networks analysis. The Lagrangian relaxation has only one Lagrangian multiplier that can only take on a limited number of values, making the search for the optimal multiplier easy. The interpretation of the optimal Lagrangian parameter is that its value is equal to the price that has to be paid to get all  $n$  objects assigned. In the given research, we show the practical application of the Lagrangian-relaxed LSAP in the quantitative analysis of social networks.

**3 - An Algorithm to Find Multiple Distinct K-clubs in an Undirected Graph**

Ali Rahim Taleqani, North Dakota State University, 310 East Bison Court, Fargo, ND, 58102, United States, Chrysafis Vogiatzis, Jill Hough

In this work, we discussed a new algorithm to identify multiple distinct highly centralized  $k$ -clubs. A  $k$ -club is connected set of nodes of a restricted diameter that is, where any two nodes are reachable within  $k$  hops using nodes inside the set.  $K$ -clubs have many applications in social network analysis, computer network, and communications. We implemented and evaluated the algorithm on a bike-sharing system.

## ■ WA08

North Bldg 124A

**Stochastic Optimization Algorithms**

Sponsored: Optimization/Nonlinear Programming

Sponsored Session

Chair: Filip Hanzely, King Abdullah University of Science and Technology, Jeddah, 23955, Saudi Arabia

Co-Chair: Nicolas Loizou

**1 - Accelerated Minibatch Coordinate Descent Method with Arbitrary Sampling**

Filip Hanzely, King Abdullah University of Science and Technology, Thuwal, Jeddah, 23955, Saudi Arabia, Peter Richtarik

Accelerated coordinate descent is a widely popular optimization algorithm due to its efficiency on large-dimensional problems. It achieves state-of-the-art complexity on an important class of empirical risk minimization problems. In this paper we design and analyze an accelerated coordinate descent (ACD) method which in each iteration updates a random subset of coordinates according to an arbitrary but fixed probability law. We therefore generalize “NUACDM” of Allen-Zhu et al (ICML 2016), which performs a single coordinate update. We also provide importance sampling for more popular mini-batch variants of ACD, which yields a faster convergence than the standard uniform mini-batch sampling.



**2 - Accelerated Sarah: Some Classical Variants**

Majid Jahani, Lehigh University, Bethlehem, PA, United States, Nicolas Loizou, Lam Minh Nguyen, Martin Takac

In this study, we propose some optimization algorithms for the finite-sum minimization problems. Our methods incorporate the ideas of Heavy Ball (HB) momentum, LBFGS and Stochastic Recursive Gradient algorithm (SARAH). The proposed methods are called HBSARAH and LBFG2SARAH, respectively. We demonstrate experimentally that our algorithms perform well on large-scale convex optimization problems.

**WA09**

North Bldg 124B

**Incentive Issues and Emerging Topics in Services**

Sponsored: Manufacturing & Service Oper Mgmt/Service Operations

Sponsored Session

Chair: Luyi Yang, Johns Hopkins University, Baltimore, MD, 21202, United States

Co-Chair: Philipp Afeche, University of Toronto, Toronto, ON, M5S 3E6, Canada

**1 - Tipping Point in Ride-hailing Service Systems with Sharing Option**

Jianfu Wang, Nanyang Business School, Nanyang Technological University, Block S3-B2C-85, 50 Nanyang Avenue, Singapore, 639798, Singapore, Geoffrey Chua, Arvind Sainathan, Akshay Vijayendiran

This paper examines different car-sharing models offered by ride-hailing firms. In the traditional car-hailing model, customers are served individually by taxis or private cars. In the sharing-only model, all customers are willing to share the ride with other customers. In the hybrid model, customers may choose either individual or shared service provided by the same fleet of cars. We develop a queueing game-theoretic model to help determine the arrival rates that create the maximum customer value. We discover a tipping point in the hybrid model. When the hassle cost decreases to this point, the optimal customer behavior switches from less than 80% using shared service to all using it.

**2 - Do Ratings Cut Both Ways? Impact of Bilateral Ratings on Platforms**

Senthil Veeraraghavan, University of Pennsylvania, Wharton School OPIM Department, 545 3730 Walnut Street, Philadelphia, PA, 19104, United States, Kartik Hosanagar, Chen Jin

Traditional platforms (e.g., Amazon) use Unilateral Rating System (URS), in which customers rate sellers. However, sharing economy platforms (e.g., Uber, Lyft, Airbnb) have adopted Bilateral Rating System (BRS) that allows service providers to rate customers, and even select customers based on ratings. BRS is often purported to be better than URS, as it unlocks the hidden information for one-time interactions, by revealing ratings of customers to service providers before they make accept/reject decisions. We find that Bilateral Ratings, despite containing more information and choice, are not necessarily better for platform revenues, and they may reduce driver revenues and consumer welfare.

**3 - Proactive Customer Service: Operational Benefits and Economic Frictions**

Kraig Delana, London Business School, PhD Program Office, London, NW1 4SA, United Kingdom, Nicos Savva, Tolga Tezcan

We study a service setting where the provider may learn about customers' future service needs and initiate service for these customers proactively if they are flexible with respect to the timing of service delivery. Utilizing both exact and asymptotic analysis, we find that proactive service can generate a significant reduction in delays for customers. Despite this, we find that customers are less willing to be flexible compared to the social optimum because of a positive externality - flexible customers benefit not only themselves but inflexible customers as well. Hence to achieve the benefits of proactive service, providers may have to incentivize customers to overcome this economic friction.

**4 - Bundle Pricing of Congested Services**

Chenguang (Allen) Wu, Hong Kong University of Science and Technology, Clear Water Bay, Hong Kong, Luyi Yang

We study whether a monopolist running a congestion-prone service system (e.g., theme park) should sell multiple services (e.g., amusement rides) separately or together as a bundle when customers are delay- and price-sensitive. We show when and how the presence of congestion challenges prescriptive guidelines proposed by the prior literature on product bundling.

**WA11**

North Bldg 125B

**Vertical Retail Supply Relationships and Assortment Management**

Sponsored: Manufacturing & Service Oper Mgmt

Sponsored Session

Chair: Stanley Lim, University of Cambridge, Cambridge, United Kingdom

Co-Chair: Min Choi, California State University

**1 - Optimizing SKU Selection for promotional Display Space at Grocery Retailers**

Olga Pak, University of South Carolina, Columbia, SC, United States, Mark Ferguson, Olga Perdikaki, Su-Ming Wu

Promotional displays are a powerful tool to boost consumer engagement. As a result, we propose a methodology to identify a profit-maximizing selection of products for promotional display using grocery store sales transaction data. Our methodology results in substantial improvement in profit when compared to an industry benchmark.

**2 - Category Captainship in the Presence of Retail Competition**

Alper Nakkas, University of Texas at Arlington, Arlington, TX, United States, Mumin Kurtulus, Yasin Alan

Category captainship (CC) is a retailing practice wherein a retailer collaborates with a manufacturer to implement a category management strategy. We consider a game-theoretic model in which two retailers compete on category appeals and analyze the impact of CC on the retail competition. We find that, CC in the presence of retail competition may enable the focal retailer to steal market share from its competitor, leading to a share shifting effect. This effect is a significant determinant of the benefits of implementing CC for a retailer. In addition, we show that despite competing head-to-head with the focal retailer, the competing retailer can benefit from the focal retailer's CC implementation.

**3 - Intertemporal Segmentation via Flexible-duration Group Buying**

Jingchen Liu, Peking University, 5 Yiheyuan Road, Haidian District, Beijing, 100871, China, Ming Hu, Xin Zhai

Motivated by the cosmetic industry, we study an innovative group buying strategy. Different from the traditional group buying, a special edition of the product is unlocked only when the number of sign-ups reaches a preset threshold, with no duration constraint. Customers need to anticipate their expected waiting time, which varies depending on their arrival time. Then such a group buying with flexible duration can result in intertemporal consumer segmentation, as different consumer segments are admitted at different times in the dynamic sign-up process. As a unique feature of group buying with flexible duration, intertemporal consumer segmentation has several nontrivial implications.

**4 - Intermediation in the Supply of Agricultural Products in Developing Economies**

Ehsan Valavi, Harvard Business School, Boston, MA, United States, Kris Johnson Ferreira, Joel Goh

The agricultural industry has been growing in developing economies, yet farmers continue to struggle. One reason for this is that farmers bear the risk of mismatched supply and demand, since farmers must make planting and harvesting decisions prior to knowing the price they can get for their crop at an auction. Recently, e-intermediaries have emerged as an alternative channel to the auction for which farmers can sell their crop; e-intermediaries use technology to inform farmers about a fixed crop price prior to harvest. We study the impact that e-intermediaries have on the supply chain.

**5 - Scan-based Trading and Bargaining Power:****A Structural Model of Vertical Retail Supply Relationships**

Stanley Lim, University of Cambridge, Cambridge, United Kingdom, Arizona State University, Tempe, AZ, United States, Min Choi, Timothy Richards, Elliot Rabinovich

Rather than exchange title for goods upon delivery to store, under scan-based trading (SBT) contracts, supplier retains title until the item is purchased by the customer. The emergence of SBT raises questions of how bilateral market power affects vertical supplier-retailer relationships in a food supply network. Using a Nash-in-Nash bargaining model, panel data combining supply and demand data, and structural econometrics, we examine the relationship between SBT contracting and degree of bargaining power exercised by retailers/wholesalers in a vertical retail channel. We find both retailer bargaining power and inventory shrink are higher under SBT than direct-to-store delivery contracts.

■ **WA12**

North Bldg 126A

**Joint Session MSOM/Practice Curated:  
Empirical and Theoretical Studies of the  
Sharing Economy**

Sponsored: Manufacturing &amp; Service Oper Mgmt

Sponsored Session

Chair: Maxime Cohen, NYU Stern, New York, NY, 10012, United States

Co-Chair: Gad Allon, University of Pennsylvania, Philadelphia, PA, 19104, United States

**1 - The Impact of Behavioral and Economic Drivers on Gig Economy Workers**

Park Sinchaisri, The Wharton School, University of Pennsylvania, Philadelphia, PA, United States, Gad Allon, Maxime Cohen

While gig economy firms benefit from increased labor flexibility, ensuring that their services appeal to independent providers poses a great challenge in planning and committing to a service capacity. We study how on-demand workers make labor decisions: when to work and for how long? Our project is in collaboration with a ride-hailing company with the goal to not only improve the way of predicting the number of active drivers, but also understand how to better recruit them, as a way to match supply and demand. Careful analysis of actual work decisions and responses to incentives, accounted for sample selection and endogeneity, has revealed behavioral insights that can inform better incentive design.

**2 - Under the Same Roof: Value of Shared Living in Airbnb**

Yao Cui, Cornell University, Ithaca, NY, 14853, United States, Ming Hu

An important difference between Airbnb and traditional hotels is that the guest may be sharing the property with the host. Due to the shared living it enables, Airbnb blurs the line between economic and social exchanges. In this paper, we study how the social exchanges affect transaction prices in Airbnb. We first offer empirical evidence that the guest's desire to stay with the host impacts transaction prices. The empirical evidence thus suggests that the guest may obtain a utility from staying with the host, which we term the social utility. We then theoretically investigate the implications of social utility for the sharing economy stakeholders.

**3 - Free-floating Vehicle Sharing Networks**

Einar Gunnarsson, University of Minnesota, Minneapolis, MN, United States, Saif Benjaafar

We describe a queueing model of free-floating vehicle sharing networks, such as dockless bikes. We characterize the relationship between service level, fleet size, and the size of the service region. We show that maintaining a high service level can require a disproportionately large fleet.

**4 - Dockless Bike-share Systems**

Ashish Kabra, INSEAD, Boulevard de Constance, Fontainebleau, 77305, France

Dockless bike-share systems have taken over the VC landscape. We study how their ridership compares and more importantly interacts with station based bike-share systems.

■ **WA13**

North Bldg 126B

**Practice- Supply Chain Management I**

Contributed Session

Chair: Konstantinos (Constantine) Moros, EY (Ernst &amp; Young) - Advisory Services, 3 Ipsilandou Street, Alimos, Athens, 17455, Greece

**1 - Implementing Blockchain Solution using Smart Contracts for Efficient Container Cargo Tracking**

Raja Jayaraman, Khalifa University, P. O. Box 127788, Abu Dhabi, United Arab Emirates, Khaled Salah

Efficient tracking of container cargo is critical in managing global trade and logistics activities. The volume of global container movement combined with information opaqueness and complexity necessitates implementing a robust technology solution with real time tracking capabilities. Blockchain is an emerging technology that offers the necessary framework to track and manage container cargo movements across the supply chain using a peer-to-peer, secured, distributed ledger. In this talk, we present the implementation approach, architectural design, interactions between sender and receiver, and testing of the overall system functionality.

**2 - Procurement Design under Asymmetric Information of Uncertain Supply**

Feng Liu, Dr., Dongbei University of Finance and Economics, Dalian, China, Qingkai Ji, Jun Zhuang

Unreliable suppliers may pose a substantial threat to supply chains, especially when they hold private reliability information. We consider a dyadic supply chain where the production yield information of supplier is asymmetric. We propose a new mechanism-design model and derive the buyer's optimal procurement contract menu that can screen the suppliers with private information. We prove that the contract menu is as simple as offering two different inflated order amounts and setting the procuring price sufficiently low to let the suppliers earn reservation profits. This paper provides some new insights into supply chain management under asymmetric information of uncertain supply.

**3 - Information Signaling of Superior Supply Chain Management Capability**

Suvankar Ghosh, University of Toledo, 2801 W. Bancroft Street, Toledo, OH, 43606, United States, John Thornton, Yewmun Yip

Exceling in managing the supply chain is a challenge. Firms with superior supply chain management (SCM) capability play a key role as other businesses try to emulate them. But businesses have to first know who these capable firms are. Information signaling models assert that having a credential can signal the requisite capability. Gartner publishes annually a list of the top 25 firms that it believes excel in SCM. We treat being in Gartner's list as a credential of superior SCM capability. We study the value of this credential from 2004 to 2014 and find worrying signs that its value may be eroding with time. This has serious implications for both Gartner and the business community.

**4 - Multi-criteria Evaluation of Supply Chain Structures**

Ravi Suman, University of Wisconsin-Madison, Madison, WI, 53726, United States, Aqueel Nazim Altaf, Ananth Krishnamurthy, Sushanta Sahu

Strategic decisions of which products to make at which facility are often influenced by a combination of quantitative factors (capacity and costs) and qualitative factors (political stability and supply reliability). We develop a decision-making framework that effectively balances these diverse factors and evaluates alternatives. The approach uses a mixed integer programming model to capture the effects of quantitative factors and a generalized TOPSIS model to address the qualitative factors. We show that the combination of the two methods provides a true assessment of alternative scenarios facilitating effective decision making.

**5 - Supply Chain Finance Program Offered by Major Retailers: A Strategic Framework of Supplier Assessment Process**

Konstantinos Moros, Senior Manager - EY Advisory Services, EY (Ernst &amp; Young) - Advisory Services, 3 Ipsilandou Street, Alimos, Athens, 17455, Greece, Daniel Corsten

The focus of this empirical research is positioned within the intersectional research area of Buyer-Supplier Relationships and Supply Chain Finance. By conducting a survey in a group of suppliers who have been exposed to, informed, and invited to adopt a SCF program, offered by one of the largest multinational retailers, we examine the main non-finance and finance related drivers of supplier-perceived satisfaction and trust and propose a strategic framework of ex-ante and ex-post assessment process followed by suppliers. We also explore the link of these two BSR constructs to the supplier perceived SCF program attractiveness and the risk of buyer opportunism, following a potential adoption.

**6 - Supply Chain & Innovation in Consumer Goods Manufacturing: The Operational Impact of New Product Introductions**

Rafael D az, Professor of Supply Chain Management, MIT-Zaragoza Logistics Center, Zaragoza, 50197, Spain, Leo Laranjeira Gomes

We analyze and measure the impact of new product introductions into the supply chain of a consumer goods manufacturer. Based on an in-depth analysis of operational panel data from a European company, we identified the factors that impact its supply chain performance and should be considered when analyzing exploration versus exploitation trade-offs.

## ■ WA14

North Bldg 126C

### Emerging Topics in Service Operations

Sponsored: Manufacturing & Service Oper Mgmt/Service Operations

Sponsored Session

Chair: Yuqian Xu, University of Illinois at Urbana-Champaign, Champaign, IL, 61820, United States

#### 1 - Evolution of Ride Services

Daehoon Noh, University of Maryland, College Park, MD, 20742, United States, Tunay Tunca, Yi Xu

Ride services bring together drivers and customers in two-sided matching markets. As these services mature multiple competing operational models emerge. In this paper, we utilize a multi-stage multi-firm model to analyze the competition between different ride service models. We study the market equilibrium and identify the factors that determine pricing and shaping of market segmentation.

#### 2 - Information and Coordination in Supply Chain Management: A Case of Fast Food Restaurant Chain

Jiahua Wu, Imperial College Business School, Imperial College London, London, SW7 2AZ, United Kingdom, Ming Hu, Peng Luo

Our study is based on a data set from a fast-food restaurant chain. During the observation window, this restaurant chain switched from third-party POS systems to their own system, which allows them to gather real-time sales information from stores. We study store managers' adjustment of operational decisions in response to this change, as well as the resulting impact on customer satisfactions. Surprisingly, customer satisfaction deteriorates as a result of this change. We show that mis-coordination between supply and system update is the reason for that.

#### 3 - The Impact of Bike Sharing on Environment

Shuai Hao, University of Illinois Urbana-Champaign, Champaign, IL, United States, Yuqian Xu, Anindya Ghose

Bike sharing is becoming more and more popular across the world and has drawn increasing attention from the operations management and other research community. However, so far as we know, limited work has been done on quantifying the environmental impact of bike sharing. This work aims to quantify the impact of bike sharing on air quality and estimate the causal effects. Also, we want to take one step further to understand the mechanism behind this impact through analyzing the public transportation data.

#### 4 - A Model of Network Formation with Heterogeneous Players

Lingjiong Zhu, Florida State University, 1017 Academic Way, Room 208, Tallahassee, FL, 32306, United States, Angelo Mele

We study an equilibrium model of sequential network formation with heterogeneous players. The payoffs depend on the number and composition of direct connections, but also the number of indirect links. We show that the network formation process is a potential game and in the long run the model converges to an exponential random graph (ERGM). Since standard simulation-based inference methods for ERGMs could have exponentially slow convergence, we propose an alternative deterministic method, based on a variational approximation of the likelihood.

## ■ WA15

North Bldg 127A

### Advances in Service Operations

Sponsored: Manufacturing & Service Oper Mgmt/Service Operations

Sponsored Session

Chair: Tarek Abdallah, New York University, New York, NY, 10029, United States

#### 1 - Nudging Flexible Workforce: Empirical Evidence from Online Cleaning Services Platform

Ruslan Momot, HEC Paris, 1 Rue de la Libération, Jouy-en-Josas, 78350, France, Ekaterina Astashkina, Marat Salikhov

This study focuses on platforms that facilitate matching of heterogeneous customers (tasks) with heterogeneous contractors. Centralized platforms (e.g. Uber) rigidly assign contractors to customers, while decentralized platforms (e.g. TaskRabbit) let contractors choose tasks they prefer. We compose the right personalized assortment of tasks that hybrid platforms should offer to its contractors. We build an econometric model of contractors' choice, which we estimate on a proprietary dataset of the cleaning platform (similar to HomeJoy). We then formulate platform's online optimization problem of assortment personalization and identify policies that achieve near-optimal performance.

#### 2 - Randomized Product Display (Ranking), Pricing, and Order Fulfillment for E-commerce Retailers

Yanzhe Lei, Queen's University, Kingston, ON, Canada, Stefanus Jasin, Joline Uichanco, Andrew Vakhutinsky

We consider an e-tailer selling multiple products stored in multiple warehouses to customers from multiple regions. For each customer, e-tailer may customize the pricing decision, the product display decision (i.e. which products to display in what order on the website), and the fulfillment decision (i.e., where to dispatch individual items from). We propose a tractable LP formulation and then construct a novel randomization scheme that translates the solutions to the LP into control parameters. We test the performance of the proposed control in large-scale numerical experiments with real retail data.

#### 3 - Revenue Management with Bundles

Tarek Abdallah, Kellogg School of Management, Northwestern University, 2211 Campus Dr, Evanston, IL, 60208, United States, Joshua Reed, Arash Asadpour

We study the impact of operational levers such as limited inventory and short selling horizons on the optimal bundling strategy. We incorporate the bundling problem into a classical network revenue management problem and go beyond the classical fluid regime. In particular, in our problem there are three main parameters that can be scaled: (1) the arrival rate, (2) the inventory, and (3) the number of product types. By considering the different ways these parameters can be scaled, we can capture different dynamics of the problem that correspond to different market properties. Our preliminary results reveal an interesting interplay between the operational parameters and the optimal selling strategy.

## ■ WA16

North Bldg 127B

### Joint Session MSOM/Practice Curated: Waste Issues

Sponsored: Manufacturing & Service Oper Mgmt/Sustainable Operations

Sponsored Session

Chair: Arzum E. Akkas, Boston University, Cambridge, MA, 02142, United States

Co-Chair: Dorothee Honhon, University of Texas at Dallas, Richardson, TX, 75080, United States

#### 1 - Package Size and Pricing Decisions with a Bulk Sale Option

Dorothee Honhon, University of Texas at Dallas, 800 West Campbell Road, SM30, Richardson, TX, 75080, United States, Ismail Kirci, Alp Muharremoglu

We investigate the package size and pricing decisions of a retailer selling a perishable product to a population of heterogeneous customers who choose between buying the product in packages of a fixed pre-set size or buying the product in bulk, which allows them to buy the exact quantity which maximizes their expected net utility. We show that, contrary to popular beliefs, the existence of a bulk sale option at the retailer's may not always be environmentally beneficial as it may, in some cases, lead to more waste at the consumer level.

#### 2 - Reducing Carbon Footprint of Grocery Retailing

Elena Belavina, SC Johnson College of Business, Cornell University, Ithaca, NY, 14853, United States, Ekaterina Astashkina, Simone Marinesi

This paper studies how e-retailing of perishables impacts market emissions. With low online adoption, inventory decentralization (due to extra stocking location of an e-retailer) is harmful and increases emissions (the result that is in line with conventional wisdom). However, with high enough adoption, the e-retailer gains enough scale, rendering decentralization, surprisingly, beneficial to the environment. Interestingly, equal demand split among retail locations leads to the worst environmental outcome. That is, we find that traditional models consider the worst kind of inventory decentralization.

#### 3 - Implications of Eliminating Aesthetic Grading in Agricultural Supply Chains

Karthik Murali, University of Alabama, 351 Alston Hall, Tuscaloosa, AL, 35487, United States, Isil Alev

The grading of produce based on aesthetics is among the biggest contributors to food waste. Using a stylized model, we explore how crop yield and consumer preferences shape the economic and environmental consequences of eliminating grading in the agricultural supply chain by introducing aesthetically differentiated produce at the retail level.



#### 4 - The Race for Product Renewal

Xabier Barriola, IESE Business School, Barcelona, Spain,  
Victor Martinez de Albaniz

The continuous renewal of products for electronics or apparel has been criticized for increasing waste. While consumers appreciate novelty in settings where product utility decays over time, it is not clear how and why producers take product renewal decisions. In this work, we build a model where consumers decide to renew their products as a function of product launches, and firms optimize product features and introduction times. We find that a monopoly leads to efficient launch decisions while competition results in an oversupply of new products.

## ■ WA17

North Bldg 127C

### Supplier Enabled Innovation and Supply Chain Management

Sponsored: Manufacturing & Service Oper Mgmt/Supply Chain

Sponsored Session

Chair: Noam Shamir, Tel Aviv University, Tel Aviv, 8, Israel

Chair: Hyoduk Shin, UC-San Diego, La Jolla, CA, 92093, United States

#### 1 - Government-to-Government (G2G) Contracts for India's Pulses Procurement: Ad-Hoc Bargaining, Long-Term Contracting and Supplier Diversification

Liying Mu, University of Delaware, Newark, DE, United States,  
Bin Hu, Srinagesh Gavirneni

India depends on pulses as a vital source of protein, yet has faced pulses crises driven by insufficient and uncertain internal yields and ad-hoc importing policies. The government is experimenting with long-term importing policies. Inspired by India's importing practice, we set out to examine G2G ad-hoc bargaining versus long-term contracts under the Nash-bargaining framework. Our main results are: (a) buyer's bargaining power does not necessarily improve its utility in ad-hoc bargaining, (b) long-term contracts can improve the buyer's utility if the buyer has sufficiently high bargaining power, and (c) bargaining power of the buyer can be improved through supplier diversification.

#### 2 - Does Competition Help Drug Shortage Recovery?

Junghee Lee, University of California, San Diego, CA, 92093-0553,  
United States, Hyun Seok Lee, Vixh Krishnan, Hyoduk Shin

There are ongoing shortages of generic drugs in the U.S., which threaten public healthcare. While manufacturing firms argue limiting competition may mitigate the issue, the FDA and patients seriously challenge the idea. Using historical drug shortage data and competition level, we reconcile both perspectives and provide better insights.

#### 3 - Data Analytics in Supply Chain Quality

Ahmet Colak, Clemson University, Greenville, SC, 29601,  
United States, Robert Bray

Combining public and private auto industry data, we derive novel consumer-level and firm-level variables that influence quality improvement decisions such as recalls. Accounting for various product characteristics and spillover effects, we study a panel data from 1994 to 2015. We use data analytics and structural estimation.

#### 4 - Organizational Design and the Ability to Exploit Complementarities: A Naturally Occurring Experiment

Changseung Yoo, McGill University, Montreal, QC, Canada,  
Anitesh Barua, Genaro J. Gutierrez

Using a naturally occurring experiment, we empirically investigate how a firm's organizational design involving centralized or decentralized decision making can affect its ability to exploit synergies among business practices in the context of digital advertising. We find that the centralized mode better recognizes and incorporates complementarities into its decision making, while the decentralized mode fails to exploit complementarities, and thus systematically under-invests in its decisions, leading to less overall profit.

## ■ WA18

North Bldg 128A

### Operations Management I

Contributed Session

Chair: Weixin Shang, Lingnan University (Hong Kong),  
8 Castle Peak Rd, Tuen Mun, Hong Kong

#### 1 - Simple Sequential Allocation Mechanisms

Kun Soo Park, Seoul National University, 1, Gwanak-ro,  
Gwanak-gu, Seoul, 08826, Korea, Republic of, Bosung Kim,  
Seyed Iravani, Sang Won Kim

We consider an allocation of a firm's capacity to its retail branches. The firm allocates the capacity to each branch to maximize the overall profit of the firm. Each branch makes ordering decision independently by using private information. We focus on the situation where an allocation to a retail branch should be made without full information about orders from other branches who may order later. We also incorporate branch manager's incentive to inflate their orders (i.e., strategic ordering) to receive a more favorable allocation.

#### 2 - Technology Upgrade in a Supply Chain with Entry Threat

Guanmei Liu, Shanghai Jiao Tong University, 1954 Huashan Rd.,  
Shanghai, 200030, China, Xiaofeng Shao

This study examines a strategy that an existing buyer (he) upgrades a supplier's production technology through direct investment when a potential buyer (she) may enter the market. We show the entry, without technology spillover, benefits the incumbent buyer under certain conditions, while it does not with technology spillover. Importantly, we reveal investing in technology upgrade may affect the concentration of the product market. Given a high production cost and a low investment cost without technology spillover, the supplier refuses to feed the entrant, incurring her entry failure and thus market monopoly. With technology spillover, it approves the entry, causing market competition.

#### 3 - Evaluating Contract Differentiation and Participation Options under Heterogeneous Agent Information

Wenbo (Selina) Cai, Assistant Professor, New Jersey Institute of  
Tech, Mec 308, University Heights, Newark, NJ, 07102,  
United States, Dashi Singham

We develop a framework for optimization of contracts for agents with heterogeneous demand distributions, where agents can have a number of demand distributions, each with a number of possible demand realizations. We develop pricing schedules for this framework under two types of contracts: 1) aggregation vs. differentiation of contract options, and 2) whether agents can choose to not participate in the future after contract commitment. We show that the principal always prefers differentiation and required participations at each time period. A dual result exists for the agents, and when participation is required, contract differentiation maximizes the overall social welfare of both parties.

#### 4 - An Empirical Analysis of Pricing Strategies for Two-sided Platforms

Onur Altintas, University of Rochester, 500 Joseph C. Wilson Blvd  
4-349, Rochester, NY, 14627, United States, Min-Seok Pang,  
Avi Seidmann

Two-Sided business platforms have gained significant economic power over recent years. However, the competitive pricing decision processes at these multi-sided platforms are highly complex due to their temporal externality effects. In this study, we present the result of an extensive longitudinal analysis of pricing strategies for competitive two-sided platform games. We analyze the participants' strategies and subsidizing behavior under different price contract structures. Our results explain how and why the winning strategy changes with the contract structure.

#### 5 - Data-driven Inventory Allocation in Bike Sharing Network

Zhenyu Gao, Tsinghua, Room 430B, Zijing Department #14,  
Beijing, 100084, China, Chen Wang

Bike-sharing network gains an expanding popularity for its effectiveness in satisfying last-mile demand. It brings a new variant to inventory management with the demand outflow of one region also being a supply inflow to another, which makes it difficult to estimate lost sales for multiple interdependent regions. We propose a novel linear statistical model to incorporate inventory levels when estimating real demand from censored observations. Inventory redeployment policies are derived from the estimation results on a rolling basis. Numerical results show that our estimation resembles the real demand and the proposed inventory policy significantly reduces lost sales of the entire network.

#### 6 - Incentive-driven Bilateral Transshipment in Inventory Competition

Weixin Shang, Lingnan University, Hong Kong,  
Qi Fu, Liming Liu

We construct a two-stage game model to examine the transshipment and inventory decisions in overlapping markets with both customer switching and transshipment. We find that there could be no transshipment, partial transshipment, or full transshipment, and obtain the conditions under which a unique equilibrium of order quantities exists. We show that transshipment may intensify or mitigate inventory competition and that there can exist a real incentive for competing firms to transship to others cooperatively. We show the existence of coordinating transshipment prices under which the transshipment and inventory decisions of the competing firms mimic those of the centralized optimal decisions.

## ■ WA19

North Bldg 128B

### Innovative Pricing Strategies

Sponsored: Revenue Management & Pricing

Sponsored Session

Chair: Pnina Feldman, University of Pennsylvania, Philadelphia, PA, United States

#### 1 - Pricing Capacity over Time and Recourse Strategies:

##### Facilitate Reselling, Offer Refunds, or Overbook?

Pnina Feldman, Boston University, 595 Commonwealth Ave, Boston, MA, 02215, United States, Gerard P. Cachon

Perishable capacity is often sold before it is used which creates the opportunity to include in the pricing mechanism a recourse strategy, such as resale, refunds and overbooking. We investigate alternative recourse strategies and the implication for firm's profit and social welfare.

#### 2 - On the Power of Bounded Memory Peak End Demand Models

Tamar Cohen, MIT, Somerville, MA, 02144, United States, Kiran Panchamgam, Georgia Perakis

We consider the problem of promotion planning for a single product, with bounded memory peak end demand. We show that when using this demand model, the optimal promotion policy will require at most two price levels. We then show that with a finite planning time horizon and a limit on the number of deviations from full price, we can find the structure of the optimal pricing policy. We characterize when the optimal policy is cyclic, as well as when a cyclic policy is not optimal. Finally, we show that even in the cases that we misclassify the demand model, and the true demand model does not fit the bounded memory peak end model, the estimation error is small. We provide an analytical bound on this estimation error

#### 3 - Intertemporal Price Discrimination via Randomized Pricing

Jiahua Wu, Imperial College Business School, Office 382, Tanaka Building, Imperial College London, London, SW7 2AZ, United Kingdom, Hongqiao Chen, Ming Hu

The undesirable, but inevitable, consequence of dynamic pricing is that consumers are trained to time their purchases strategically. We consider a novel randomized pricing approach, where the firm varies prices in a random fashion, and study its effectiveness in addressing consumers' strategic behavior. We show that the optimal price distribution follows a simple structure. We also benchmark the optimal randomized pricing policy against optimal static pricing and cyclic pricing policies, and characterize conditions when the former dominates. Lastly, we extend randomized pricing in two different directions, namely, cyclic randomized pricing and Markovian pricing.

#### 4 - Revenue Optimization under a Preannounced Dynamic Price Function

Dana Pizarro, University of Chile, Beauchef 851, Santiago, 8320000, Chile, Jose Correa, Gustavo J. Vulcano

We consider a dynamic game between a seller and a single buyer. The seller operates over an infinite time horizon. At the beginning of the horizon the seller commits to a price function  $p(t)$ . The buyer arrives according to a general random process, has a private valuation for the item, and decides when to buy in order to maximize his expected utility. The seller's problem is to determine the price function  $p(t)$  to maximize her expected revenue. We analyze this dynamic game and provide numerics to show the achievable revenue performance.

## ■ WA20

North Bldg 129A

### Revenue Management in Retail and Online Platforms

Sponsored: Revenue Management & Pricing

Sponsored Session

Chair: Yanzhe Lei, University of Michigan, Ann Arbor, MI, 48104, United States

Co-Chair: Stefanus Jasin, University of Michigan, Ann Arbor, MI, 48105, United States

#### 1 - Online Demand Fulfillment under Limited Flexibility

Zhen Xu, Columbia University, New York City, NY, United States, Rachel Q. Zhang, Jiheng Zhang

We extend the work by Asadpour et al. (2016) on online demand fulfillment for systems with the same number of resources and request types to general systems and show that a positive Generalized Capacity Gap (GCG) introduced by Shi et al. (2016) is both necessary and sufficient for a system to achieve bounded performance. Both theoretical and numerical evidence point to the GCG as the most important indicator of system performance, which leads to simple inventory

allocation rules and guidelines for designing sparse network structures such as generalized long chains. A real case study is conducted to confirm our findings as well as some of the flexibility principals conjectured in the literature.

#### 2 - Management and Effects of In-store Promotional Displays

Oguz Cetin, University of North Carolina, Chapel Hill, NC, United States, Adam J. Mersereau, Ali Kemal Parlakturk

We examine a brick-and-mortar retailer's choice of which product to include in a promotional display. The display provides a visibility advantage to both the featured product and its category, but it also has consequences for customer traffic and substitution. While there has been considerable academic interest in the assortment planning problem and in the shelf-space allocation problem, little attention has been paid to the problem of where to place products in the store. We develop analytical insights using a problem formulation based on a nested multinomial logit model. Our work provides guidance for how retailers can use and value promotional displays effectively.

#### 3 - Dynamic Pricing under a Static Calendar

Jinglong Zhao, Massachusetts Institute of Technology, 77 Massachusetts Avenue, E17 IDSS 495G, Cambridge, MA, 02139, United States, Will Ma, David Simchi-Levi

Our work is based on the classical dynamic pricing problem. From our collaborations with a large Consumer Packaged Goods company, we have found that while they appreciate the advantages of dynamic pricing, it is operationally beneficial for them to plan out a deterministic price calendar in advance. It is possible to deviate from this calendar as demand is observed, but there is a significant overhead in doing so, and thus deviation should be reserved for situations where the realized demand was drastically higher or lower than expected. Motivated by this, we formulate the dynamic pricing problem under static calendar constraints, and study how classical dynamic pricing intuition may break down.

#### 4 - Contingent Stimulus in Crowdfunding

Longyuan Du, Rotman School of Management, University of Toronto, 105 St George St, Toronto, ON, M5S 3E6, Canada, Ming Hu, Jiahua Wu

We study a model where backers arrive sequentially at a crowdfunding project. We characterize the dynamics of the pledging process. To boost success, we focus on a commonly practiced stimulus policy of running promotions, e.g., on social media, to attract backers. We show that the optimal promotion intensity depends on the pledge progress and is not monotone. We analyze the deterministic heuristics and show that their performances are compromised because of the all or nothing nature of crowdfunding. We propose a modified resolving heuristic that greatly improves the performance and has provable optimality gaps. Testing with the Kickstarter data, we demonstrate the benefit of the stimulus policies.

## ■ WA21

North Bldg 129B

### Practice- Optimization I

Contributed Session

Chair: Maziar Sanjabi, University of Southern California, Los Angeles, CA, 90007, United States

#### 1 - Job Scheduling with Simultaneous Assignment of Machines and Multi-skilled Workers: A Mathematical Model

Cinna Seifi, Research Assistant, Clausthal University of Technology, Julius-Albert-Strasse, Clausthal-Zellerfeld, 38678, Germany, Jürgen Zimmermann

The primary task of mining companies is the extraction of raw materials. Based on a planning program, a certain quantity of materials is expected to be extracted within a given time horizon. The applied mining method is characterized by nine process steps each of which has to be executed by an appropriate machine and worker. The processing time of a process step depends on the assigned devices and workforces. In this paper, we formulate a mathematical program for a simultaneous assignment of devices and personnel to a selection of jobs. The aim is to minimize the difference between the predetermined quantity and the amount of extracted material, cumulatively over all the process steps, for a work shift.

#### 2 - Effective Rules of Thumb in Analytics Modeling

Yanqi Xu, Director of Applied Technology, Princess Cruises, Valencia, CA, 91355, United States

Various industries build optimization models to provide meaningful solutions to practical problems so as to increase revenue, reduce costs, manage risks, streamline operations, etc. In this talk, we will share our model building experience and lessons learned across different industries. Topics (with real world examples) include: number one concern of model building, how to solve the problem at the right level of details, what to include/exclude, signs that the issues of a model cannot be fixed by incremental improvement, performance tradeoffs, and modeling with sparse data.

### 3 - Generative Adversarial Network Formulations with Convergence Guarantees

Maziar Sanjabi, USC, Los Angeles, CA, United States

Generative Adversarial Networks (GANs) are one of the most practical strategies to learn data distributions. A popular GAN formulation is to use Wasserstein distance as a metric between probability distributions. Unfortunately, minimizing this distance is difficult as its objective is non-convex and non-smooth. In this work, we use smooth approximations of this objective. We show that obtaining gradient information of the smoothed formulations is easy. Based on this observation, we propose a class of first-order algorithms with guaranteed theoretical convergence to stationarity. We apply our method to MNIST and CIFAR-10 datasets and show its effectiveness.

## ■ WA22

North Bldg 130

### Practice- Pricing and Revenue Management I

Contributed Session

Chair: Hao Lu, University of Science and Technology of China, 96 JinZhai Road, Baohe District, Hefei, 230026, China

#### 1 - Which Outlier Detection Approach is Better for Estimating the Elasticity Value

Shuguang Ji, Sr. Data Scientist, Delta Airlines, Atlanta, GA, 30339, United States

In cases where outliers are present, finding an accurate model to make prediction becomes more difficult. In practice, the mean  $\pm$  3 standard deviations remains common method for outlier detection. Unfortunately, 3 problems can be identified when using this method. Firstly, it assumes that the distribution is normal. Secondly, the mean and standard deviation are strongly impacted by outliers. Thirdly, this method is very unlikely to detect outliers in small samples. In this presentation, the author wants to review the popular outlier detection methods for the elasticity estimation at first. Then the most effective detection methods will be recommended according to the cases in practice.

#### 2 - Pricing and Service Throttling in Cloud Computing

Yingda Zhai, The University of Texas at Austin, Austin, TX, 78703, United States, Maxwell B. Stinchcombe, Andrew B. Whinston

Motivated by unprecedented surging demand for computing resource, we consider a monopoly provider with queue technology prices and allocates computing resource in a complex environment. We establish a service model with no aggregate risk which allows provider accurately to predict and manage queue capacity. A profit-maximizing provider throttles service by (i) limiting overall market supply and (ii) tranching her capacity in terms of service quantity and interruption. We then propose an appealing auction mechanism in the cloud computing spot market to implement the profit-maximizing allocation where users find it a weakly dominant bidding strategy to bid the optimal prices.

#### 3 - Dynamic Pricing Strategy and Simulation Research Considering Strategic Consumers in Perfect Competition Electricity Market

Lingchunzi Li, Huazhong University of Science and Technology, School of Management, No. 1037, Luoyu Road, Hongshan District, Hubei Province, China, Wuhan, 430074, China, Haijun Wang, Nancy Shuoqia Guo, Penghong Cheng

China is in the key stage of electricity market reform. This paper is to explore an appropriate pricing strategy to provide reference for reformation and power pricing research in China. Under centralized transactions, a game model considering customers' strategic choice behavior is established. And a time-sharing dynamic pricing scheme is solved to maximize both power enterprises' equilibrium revenue. Simulation results show that the competition between power producers can reduce power price and increase power supply volume effectively. The model we built and the factor of equilibrium validity we introduced are innovations in this paper.

#### 4 - An Optimization Framework for Pricing of Port Services: Case of Major Ports in India

Deepankar Sinha, Associate Professor, Indian Institute of Foreign Trade, 1583 Madurdah, Kolkata, 700107, India

Ports enable inter and intra-modal cargo transshipment to and from ships. The cost incurred in ports impact the total landed cost of any maritime cargo. The ports need to achieve three basic objectives. One, it needs to be efficient in achieving the desired level of productivity with optimal use of resources; second, minimize cost of operation; and third minimize total landed cost of shippers. So far, studies and researches have focused on part of these objectives. In this paper an attempt has been made to encompass all the three objectives. It proposes to use a non-parametric approach to develop a multi-objective optimization model to arrive at a rational pricing framework for port services.

### 5 - Multinational Merger and Acquisition and Market Value of China's Service Enterprises in the Belt and Road Strip

Hao Lu, PhD Student, University of Science and Technology of China, 96 JinZhai Road, Baohe District, Hefei, 230026, China

The Belt and Road strip (BRS) provides a broad stage for Chinese service enterprises to enter into M&As overseas. However, whether such multinational M&As achieved the expected market value return? This paper uses event study methods to analyse the development of multinational M&As in the service industry in BRS for the period 2013-2017. We found that since 2013, most of China's multinational service M&As have achieved significantly positive abnormal returns (ARs). The ARs of M&As in the technology services and public services were found to be more significant than other sub-industries of service. Among the factors that affect AR, the ratio of M&A contract size is the most significantly positive.

## ■ WA23

North Bldg 131A

### Systemic Risk and Financial Risk Management

Sponsored: Finance

Sponsored Session

Chair: Luitgard Veraart, London School of Economics and Political Science, Houghton Street, London, WC2A 2AE, United Kingdom

#### 1 - Optimal Portfolio Allocations in a Heterogeneous Banking System

Marko Weber, Columbia University, New York, NY, United States

We study the portfolio choice implications of leverage constrained banks, which may need to deleverage in response to price shocks to satisfy regulatory requirements. Banks select their asset holdings in order to minimize their expected execution costs. Consistent with the classic theory of portfolio selection, diversification is optimal if each bank neglects the impact caused by the other agents' liquidation actions. If banks are heterogeneous in their leverage ratios, in equilibrium they reduce portfolio overlapping and seek diversity, at the expenses of sacrificing diversification benefits on the individual level. The bank's equilibrium allocation is not socially efficient. A benevolent social planner aiming at minimizing liquidation costs should provide banks with incentives to increase their diversity.

#### 2 - Interbank Clearing in Financial Networks with Multiple Maturities

Luitgard Veraart, Associate Professor, London School of Economics and Political Science, Houghton Street, Department of Mathematics, London, WC2A2AE, United Kingdom, Michael Kusnetsov

We consider the problem of systemic risk assessment in interbank networks in which interbank liabilities can have multiple maturities. We develop a clearing mechanism for the interbank liabilities to deal with the default of one or more market participants. Our approach generalises the clearing approach for the single maturity setting by Eisenberg & Noe (2001). We show that in the context of multiple maturities, specifying a set of defaulted banks is challenging. We propose two approaches to overcome this challenge: an algorithmic and a functional approach. Our analysis permits construction of simple dynamic clearing models.

#### 3 - Buffered Probability of Exceedance (bPOE) Ratings

Stan Uryasev, University of Florida-Gainesville, AOD, 303 Weilhall, Gainesville, FL, 32611, United States, Giorgi Pertaia

Credit ratings are widely used by investors to assess the credit risk of a security. The financial crisis of 2008 showed that credit ratings might not measure the risk appropriately for the synthetic instruments such as CDOs. This paper presents a new rating assignment model based on Buffered Probability of Exceedance, that is an improvement over the current POE based methodology.

#### 4 - Risk in Production Networks

Peng-Chu Chen, The University of Hong Kong, Kowloon, Hong Kong

We investigate systemic risk in a production network, where firms are connected through demand and supply orders. A financial shock causing disruptions to some firms propagates through the supply-chain network via the input-output linkages between suppliers and customers. Each firm in the network takes contingency plans to mitigate the impact generated from disruptions and reroutes orders through different suppliers. An equilibrium is reached when contagion from disruption stops. We develop an algorithm to recover the equilibrium with the greatest amount of delivered orders. We then analyze the impact of industrial integration on systemic risk in the production network."



## ■ WA25

North Bldg 131C

### Service Queueing

Sponsored: Service Science

Sponsored Session

Chair: Thomas Robbins, East Carolina University, 3212 Bate Building, Greenville, NC, 27858, United States

#### 1 - Evaluating Tail Performance of Queueing Systems Using a Novel Stochastic Ordering Approach

Hung T. Do, Assistant Professor, University of Vermont, 55 Colchester Ave., 207 Kalkin Hall, Burlington, VT, 05405, United States, Masha Shunko, Alan Scheller-Wolf

In some service systems, performance in the right tail of the queue size and/or waiting time distribution is the main source of managerial concern. We propose a new perspective on analyzing performance of such systems by defining new stochastic orders to compare the tail of distributions and performance measures.

#### 2 - Call Center Staffing with Uncertain Dependent Arrival, Service, and Abandonment Rates

Tahir Ekin, Assistant Professor of Quantitative Methods, Texas State University, 601 University Dr. McCoy 451, San Marcos, TX, 78666, United States, Tevfik Aktekin

Many stochastic service models assume the system (arrival, service, and abandonment) rates to be deterministic inputs and those that treat them as uncertain assume they are independent. We propose methods for determining the optimal number of servers of a service system while modeling the system rates as dependent random variables. In doing so, we take the Bayesian point of view of inference and obtain joint posterior distributions of these system rates. Then, we utilize an augmented probability simulation based optimization method to solve the resulting decision model. We illustrate the proposed method and implications of ignoring dependence in system rates using real world call center data.

#### 3 - Balancing Service Speed and Agent Utilization for an Online Insurance Platform

Andres I. Musalem, U. of Chile, Beauchef 851, Santiago, 8370456, Chile, Marcelo Olivares, Daniel Yung

We study an online platform that sells car insurance policies. Customers who do not purchase online are then contacted via telephone. We find that as the time that it takes the platform to contact a customer increases, the probability that the customer purchases an insurance policy decreases. Hence the platform might gain from improving the speed at which it contacts its website visitors, for example by hiring more agents, which however affects their utilization and compensation. We empirically study this trade-off for the platform where on the one hand a greater call center capacity leads to better speed of contact but also reduces the incentives for experienced agents to keep their jobs at the platform.

#### 4 - An Exact Algorithm for the Service Bundles Design Problem

Yifu Li, Hong Kong University of Science and Technology, Clear Water Bay, Kowloon, 999077, Hong Kong, Xiangtong Qi

The service sector has become to dominate the global economy and evolves at a fast speed. Among the vast category of the service product, experiential service has become an indispensable part of our daily life. A crucial problem is how to create service bundles with given activities in considering both customer experience and practical constraints. Based on the results of the experiential studies, we model and analyses the service bundles design problem, which is proved to be a binary sum of ratios problem. We develop a geometric branch and bound algorithm to solve it to optimality and improve the algorithm with several techniques. It has been tested to be more efficient than the traditional algorithms.

#### 5 - The Impact of Order Ahead Apps on Fast Food Queues

Thomas Robbins, Associate Professor, East Carolina University, 3136 Bate Building, Greenville, NC, 27858, United States

Order ahead mobile apps are becoming increasingly popular at Quick Serve Restaurants. These apps allow customers to pre-order their meal and skip the line when arriving at the store. In this talk we investigate the hybrid queuing system created by these applications. Using discrete event simulation we examine the impact these apps can have on system performance for customers who use the app, customers who do not, and the system as a whole.

## ■ WA26

North Bldg 132A

### Smart Service Systems with AI and Blockchain

Sponsored: Service Science

Sponsored Session

Chair: Chiehyeon Lim, UNIST, Ulsan, 44919, Korea, Republic of

#### 1 - Development of a Context-aware Serendipitous Recommendation System

Changhun Lee, UNIST School of Management Engineering, Ulsan, Korea, Republic of, Gyumin Lee, Chiehyeon Lim

Recommendation system development has been an important domain over last several decades. However, as technique has improved and research on recommendation system increased, the importance of developing a “serendipitous” recommendation system has emerged. For that, we paid attention to the latent feature the items are recognized. We assumed that people would move from an item to a next item through a latent feature reflected in a sequence of items. We indirectly show latent features by presenting a topic map, and suggest a context-aware based serendipitous recommendation system. Our interim result seems only context-aware-accurate, but at least showed a possibility of being serendipitous.

#### 2 - Understanding Relations among ERP Success Factors: A Quantitative Approach based on Association Rules Mining

Jonghyeon Ko, UNIST School of Management Engineering, Ulsan, Korea, Republic of, Marco Comuzzi

The critical success factors (CSFs) of ERP implementation have been widely researched on the definition and the rank of CSFs and categorization according to each type of companies. The CSFs of ERP implementation is related and affected each other so that a lot of experts and researchers have studied different interrelationships among CSFs of ERP implementation and conceptual model of interrelationships. This paper approaches to this problem differently with data-driven model using a company data-set from literatures. The association rule method is used to find interrelationship among groups of CSFs as well as each factor of CSFs. The result shows the entire interrelationships of CSFs with numerical metrics representing the direction and strength of rule.

#### 3 - Mechanism and Development of Blockchain-based Smart Service Systems

Chiehyeon Lim, UNIST, Room #606-5, Building #114, Ulsan, 44919, Korea, Republic of, Marco Comuzzi, Byoung Ki Seo

In this presentation, first, we define the mechanism how the blockchain technology can contribute to improving service systems. Second, we report R&D project cases on the development of blockchain-based smart service systems. Third, we discuss implications of our work to the Service Science theory and practice.

#### 4 - Smart Services in European Mechanical Engineering Companies

Thomas Meiren, Fraunhofer IAO, Nobelstr. 12, Stuttgart, 70569, Germany, Anastasia Tzitimidou

Digitally supported services like advanced remote condition monitoring, predictive maintenance, new control and automation solutions as well as profiling and behaviour tracking play an increasing role in mechanical engineering industry. They are making use of the growing volume of data that is being captured every day and are combined in innovative ways in order to create on-demand, personalized solutions for customers. Moreover, product performance and customer behaviours will get visible as they have never been before. The conference presentation will show results from an empirical study within the European mechanical engineering industry.

## ■ WA28

North Bldg 221A

### Practice- Logistics 1

Contributed Session

Chair: Josue Velazquez Martinez, Massachusetts Institute of Technology, Cambridge, MA, 02139, United States

#### 1 - A Unified Dynamic Control for Energy-aware Electrical Vehicle Operations

Seokgi Lee, Assistant Professor, University of Miami, 1251 Memorial Drive, McArthur Engineering Building, Room 281, Coral Gables, FL, 33146, United States, Hyun Woo Jeon

This study investigates the time and cost benefits that can be gained by the integrated control of EMV operations combined with an energy consumption prediction. Dynamic models for EMV charging capacity and operations control systems will be developed and serve as a scientific basis for a unified control algorithm, in which charging capacity, routing, and battery charging schedules of EMV are simultaneously controlled in a real-time manner. An electrical load variation at the warehouse facility level will be predicted by developing a novel electrical load forecasting model based on cutting-edge machine learning techniques, which will serve as important guidelines for unified decision-making.

## 2 - Real-time Package Consolidation for Split Orders in Online Retailing

Yuancai Zhang, Dalian University of Technology, Office Room A1214 Innovation Park Building, Dalian, 116024, China  
Yuancai Zhang, University of Arizona, Tucson, AZ, 85719, United States, Xiangpei Hu, Wei-Hua Lin

The order splitting has been one of the main challenging problems for multi-item order fulfillment in online retailing. The key issue to fulfill split orders with fast-delivery options in lower costs is: how to make package consolidation (consolidating and packing items of several sub-orders together) decisions in real-time using capacitated warehouses. We formulate an analytic model and propose a rolling horizon based heuristic algorithm to generate efficient real-time package consolidation schemes for online retailers.

## 3 - A Benders Decomposition Algorithm for the Fulfilment Planning Problem of an Online Retailer with a Self Owned Logistics System

Shuqin Li, Shanghai Jiao Tong University, No.800 Dongchuan Rd., Shanghai, China, Shuai Jia

We consider an order fulfilment planning problem in an e-tailing environment. For each planning period, the e-tailer makes decisions for assigning orders to the fulfilment centers and the delivery stations, as well as the decision for shipping orders under a time window constraint. We develop a mixed integer program to minimize the order processing cost and shipping cost. We show that the problem is strongly NP-hard, and propose a benders decomposition algorithm for solving the problem. We evaluate the computational performance of the algorithm on problem instances that are generated based on the logistics network of JD.com, a leading e-tailer in China who operates a self-owned logistics system.

## 4 - How Survival of Micro Retail Companies Affects Logistics Costs in Large Consumer Packaged Goods Companies

Josue Velazquez Martinez, Research Scientist, Massachusetts Institute of Technology, Cambridge, MA, 02139, United States, Ximena Castanon Choque, Christopher Mejia Argueta, Jan C. Fransoo

In developing economies, many mom-and-pop stores disappeared per year due to a lack of productivity, while many others appeared because of low barrier of entry. Therefore, the overall micro-retailing market grows per year and represents from 40-70% of demand of large CPG companies. In this paper, we study the impact of these dynamics on logistics costs. We discuss a practical case for a distributor in Mexico City, and by using cost-to-serve estimations and continuous approximation models for routing; we show that by improving survival rate, we may avoid losses in logistics costs up to 30%.

## ■ WA29

North Bldg 221B

## Joint Session TSL/Practice Curated: Patrolling and Service Delivery Problems

Sponsored: TSL/Urban Transportation

Sponsored Session

Chair: Rajan Batta, University at Buffalo (SUNY), Buffalo, NY, 14260, United States

## 1 - Taking Out the Guesswork: An Analytics Approach to Police Contraband Searches

Anthony Bonifonte, Denison University, 3267 Raccoon Valley Rd, Granville, OH, 30106, United States, Tong Zhou

Police searches of vehicles stopped for traffic violations can seize contraband and improve public safety, but unnecessary searches are time consuming and can lead to community ill will. Using publicly available data, we develop an analytics approach to assisting officer decisions in whether to search a vehicle or not. Using variables such as time and location of stop, we create an objective estimate of whether a vehicle search will discover contraband. We adopt a reject inference approach to account for having outcome data only for vehicles searched. These findings can improve the use of police time and safety, while simultaneously reducing bias in decisions and improving community relations.

## 2 - Using the Hypercube Queueing Model for Response to Jobs with Degradation

Rajan Batta, University at Buffalo (SUNY), 410 Bell Hall, Buffalo, NY, 14260, United States, Fatemeh Aarabi

The problem of scheduling dynamically arriving jobs over a region is considered, with the features of job degradation, travel time, and multiple servers. A modification of the Hypercube queueing model is studied to address job degradation considerations. A 3 server example is presented along with optimization of response areas, server dispatch preferences and idle server management. Numerical results will be provided.

## 3 - Post Disaster Assessment Routing

Bahar Yetis, Bilkent University, Ankara, Turkey, Buse Eylul Oruc

We propose a post-disaster assessment strategy as part of response operations. The arcs and nodes to perform assessment activities on are selected based on the value they add to the consecutive response operations. The model considers motorcycles, which can be utilized under off-road conditions, and/or drones. The first objective aims to maximize the total value added by the assessment of the road segments (arcs) and the second maximizes the total profit generated by assessing points of interests (nodes). An epsilon-constraint method and a heuristic is proposed. To test the mathematical model and the heuristic method, a data set belonging to Kartal district of Istanbul is used.

## ■ WA30

North Bldg 221C

## Computational Problems in Warehousing and Order Picking

Sponsored: TSL/Facility Logistics

Sponsored Session

Chair: Sabahattin Gokhan Ozden, Penn State University, Abington, PA, United States

## 1 - Wait or Start? A Dynamic Warehouse Order-picking Process Phenomenon

Atieh Madani, University at Buffalo (SUNY), Buffalo, NY, 14260, United States, Rajan Batta, Mark Henry Karwan

This study focuses on optimizing warehouse order picking process in a dynamic environment. The logic behind this process determines the timing for any picker to start the tour to pick up the items of orders. The number of items in the picking list has the opposite effect on transportation cost and customer waiting time and this phenomenon brings us to one of the challenging problem in warehousing. Our approach to solve this problem involves probabilistic methods such as dynamic programming along with a heuristic on TSP to calculate the expected length of tour for the future periods.

## 2 - Optimization of a Fast-pick Area in a Cosmetics Distribution Center

Alice E. Smith, Auburn University, 3301 Shelby Center, Dept of Industrial/Sys Engineering, Auburn, AL, 36849, United States, Mario Velez Gallego

Fast-pick areas are used in warehouses to improve labor efficiency by concentrating picking activities within a compact area, minimizing the distance traveled by the pickers. One problem that must be solved when a fast-pick area is to be implemented is the assignment-allocation problem. This deals with deciding which products should be assigned to the fast-pick area, and how much space should be allocated to these products. This research was motivated by the picking operation of a cosmetics distribution center where several fast-pick areas are in place. A mixed integer linear programming formulation is proposed for solving the variant of the assignment-allocation problem found in this company.

## 3 - The Aisle Design Problem for Order Picking Warehouses

Kevin Gue, University of Louisville, Louisville, KY, 40292, United States, Alice E. Smith, Sabahattin Gokhan Ozden

The aisle design problem is to arrange picking and cross aisles in a warehouse such that expected distance to store or retrieve items is minimized. This problem has been addressed for unit-load warehouses, in which workers must visit only one or two locations per tour, but until now not for order picking warehouses, in which workers must visit many locations. We present results of a multi-year quest for the best aisle designs for order picking. Our computational system produced many interesting designs unknown to theory or practice, but surprisingly, none is significantly better than traditional designs. We conclude that current practice is likely the best practice.

## 4 - A Computational System to Solve Warehouse Aisle Design Problem

Sabahattin Gokhan Ozden, Penn State Abington, 1600 Woodland Rd., Abington, PA, 19001, United States, Alice E. Smith, Kevin Gue

We develop a warehouse layout optimization system that models layouts, allocates products to storage locations, calculates routing distances, and performs heuristic optimization over a comprehensive set of layout design parameters. The system searches over 19 different design classes simultaneously by using a layout encoding. The system is scalable which means that certain calculations such as routing can be distributed to run on multiple computers to decrease the overall computational time. It can solve optimization experiments or single design assessments in batch. In this way, researchers can create design of experiments in Excel and import it to the system to get the results.

## ■ WA31

North Bldg 222A

### Transportation-Planning I

Contributed Session

Chair: Albert Schrottenboer, University of Groningen, Vlasstraat 19, Groningen, 7912KS, Netherlands

#### 1 - A Simulation Approach to the Stochastic Vehicle Routing Without Fitting Demands

Robert A. Russell, University of Tulsa, Finance & Operations Mgmt Dept, 800 South Tucker Drive, Tulsa, OK, 74104, United States, Wen-Chyuan Chiang, Lijian Chen

We propose a method to solve the Stochastic Vehicle Routing Problem (SVRP) with stochastic demands. We realize that the distributional information of customer demands is, at best, empirical data only and the real-life SVRPs would be in a very difficult form. In this paper, we discuss the similarity of different demand scenarios and remove many scenarios, which are quite similar to each other. By greatly reducing the number of scenarios, we build a tractable SVRP model with a large number of demand scenarios considered. We then compared our model with two other models: the metaheuristic of vehicle routing, and the vehicle routing model with two-stage recourse.

#### 2 - Freight Mode Choice: A Machine Learning Approach

Rodrigo Mesa Arango, Florida Institute of Technology, Melbourne, FL, 32901, United States

Presents a machine learning application for mode choice prediction in freight transportation planning. Discusses model training through algorithm selection, model parameter optimization, and over-fitting avoidance. Contrasts challenges and opportunities related to classic econometric approaches. Employs 4.5 million shipments available in the 2012 Commodity Flow Survey Public Use Microdata for model estimation/validation.

#### 3 - Proactive Medical Transportation Planning

Mohammed Skiredj, PhD Student, École Nationale Supérieure des Mines de Saint-Étienne, 158 cours Fauriel, Saint-Étienne, 42023, France, Xiaolan Xie, Thierry Garaix

This work treats a real-life health-care transportation problem for Non-Emergency ambulance service. The problem can be seen as a multi-trip pickup and delivery problem with time windows and Trip-Crew-Vehicle assignment. The objective is to serve as many patients as possible, minimizes the total distance traveled by vehicles, and finally preserves as far as possible the forecaster starting and ending time of each driver. To solve the problem we proposed an adaptive large neighborhood search metaheuristic that uses a constructive greedy heuristic to build the initial solution.

#### 4 - Data-driven Methodology for Bicycle use Propensity Estimation

Pablo Andrés Uriza-Antorveza, Universidad de los Andes, Edificio Mario Laserna Cra 1 Este No 19A - 40, Bogotá, 10101, Colombia, Sergio Cabrales, Andres L. Medaglia, Olga L. Sarmiento

As part of adopting greener and healthier lifestyles, local governments are promoting bicycle use by implementing policies linked to the built environment. As part of a larger analytics framework designed to support transit planners, we developed a bicycle-use propensity model that lies at the core of the decision support system and feeds from geospatial data from different sources. We illustrate how the proposed method is able to support strategic decisions by quantifying the impact of a policy with data from Bogotá (Colombia).

#### 5 - Robust Fleet Size and Mix at Offshore Wind Farms

Albert Schrottenboer, PhD Candidate, University of Groningen, Groningen, Netherlands, Evrim Ursavas, Iris F. Vis

We introduce the Robust Fleet Size and Mix Problem (RFSMP) inspired by vehicle chartering decisions at offshore wind farms. A novel multi-commodity flow formulation is proposed and reformulated by means of a Dantzig-Wolfe decomposition into a set partitioning-like formulation. This leads to a master problem of which both the number of rows and the number of columns is extremely large. In addition, the number of subproblems depends on the number of included scenarios. In this talk, we discuss an exact approach based on column generation that is capable of solving the RFSMP.

## ■ WA32

North Bldg 222B

### Practice- Vehicle Routing I

Contributed Session

Chair: Amro El-Adle, University of Massachusetts, 121 Presidents Drive, Amherst, MA, 01003, United States

#### 1 - Vehicle Routing Problem with Overlapped Time Windows on Shipping from Online Store

Takashi Irohara, Professor, Sophia University, 7-1 Kiou-cho, Chiyoda-ku, Tokyo, 102-8554, Japan

Due to expansion of online shopping market, online store is increasing. Many companies are focusing on improving delivery as it leads to greater customer satisfaction and reduced delivery costs. In many companies, delivery of online stores is delivered with shifted time window by several hours from the time window, in addition to the conventional time window, in order to improve the usage rate of delivery docks. This is called an overlapped time window. In this paper, we aim to contribute to the delivery planning of online store by proposing a model of delivery planning considering overlapped time window and approximate solution using simulated annealing.

#### 2 - Solving Real World Vehicle Routing Problems at Scale

Bhanu Krishna Potluri, Llamasoft Inc., Ann Arbor, MI, 48104, United States

Vehicle routing problems are known to be notoriously difficult to solve. Modeling real-world constraints such as pickup-delivery time windows, driver hours of service, fleet sizing, etc. further increases complexity. With expanding logistics networks and ever increasing global freight volumes, businesses want to solve problems of realistic scale with real world constraints. This session explores meta-heuristics and cloud computing to achieve scalability of vehicle routing algorithms.

#### 3 - Allowing for Re-optimisation in the Vehicle Routing Problem with Time Windows, Stochastic Customers and Stochastic Demand: Model and Solution Methods

Vincentius Cornelis Gerardus Karels, PhD, Technical University Eindhoven, Duikerstraat 12 Bis, Utrecht, 3582 TB, Netherlands, Lucas Petrus Veelenturf, Tom Van Woensel

We solve a vehicle routing problem with both deterministic and stochastic customers and stochastic demands. For the deterministic customers furthermore self-imposed time-windows are determined. The problem is modeled as a two-stage stochastic programming model. Whereas most similar problems allow for simple recourse in the second stage, we allow for re-optimisation. This introduces additional complexity in the model, for which we will introduce novel solution methods.

#### 4 - Multi-depot Electric Vehicle Routing Problem with Time Windows Considering Non-linear Charging and Discharging

Surendra Reddy Kancharla, Indian Institute of Technology Madras, #238, Building Sciences Block, Alumni Ave, Chennai, 600036, India, Gitakrishnan Ramadurai

A new variant of Electric Vehicle Routing Problem with Time Windows (EVRPTW) to find the routes and charging schedules of vehicles operating from multiple depots with the objective of minimizing energy consumption is proposed. The present variant does not limit the number of visits to a charging station and considers non-linear charging and discharging. A mixed-integer program is formulated and an effective heuristic solution algorithm is presented.

#### 5 - A Vehicle Routing Problem with Drones

Amro El-Adle, University of Massachusetts Amherst, 121 Presidents Drive, Amherst, MA, 01003, United States, Mohammad Reihaneh, Ahmed Ghoniem

We investigate a vehicle routing problem with drones (VRPD) in which customers may be served either by delivery vehicles or by unmanned aerial drones launched from the vehicles. Building on the success of branch-and-price (BP) algorithms for vehicle routing problems, we use a labeling algorithm that generates synchronized drone and vehicle routes. We demonstrate the usefulness of the proposed methodology in our computational study.

## ■ WA33

North Bldg 222C

### Inventory Management I

Contributed Session

Chair: Shunichi Ohmori, Waseda University, Room 0903A, Okubo 3-4-1, Shinjuku, Tokyo, Japan

#### 1 - Determination of Order Amounts for Multiple Spare Parts of Products in the Post-production Phase

Nicholas William Leifker, Associate Professor, St. John Fisher College, 3690 East Ave., Rochester, NY, 14618, United States, Timothy Joe Lowe, Philip C. Jones

Manufacturers often encounter difficulties in supplying an adequate number of spare parts for a product that is in its post-production phase. As a result, manufacturers will sometimes make one final order of spare parts, which is used to satisfy any demand for spare parts going forward. This order may be complicated if the failure rate for one type of spare part is partially dependent on the demand for other types of spare parts, if the failure rate of the product is partially dependent of the failure rates of its parts, or if it becomes advantageous for a spare part to be salvaged. We compare two solution methods to find the order amount: a dynamic programming method, and an iterative optimization method.



## 2 - Optimal Cooperative Stocking Policy under Demand and Lead-time Uncertainties with Space Constraint and Penalty for Late Delivery

Md Shahriar Jahan Hossain, Louisiana State University, 4141  
Burbank Dr. Apt. 3, Baton Rouge, LA, 70808, United States,  
Bhaba R. Sarker

This research presents a single-vendor single-buyer cooperative inventory model for a nonperishable item. The model deals with both demand and lead-time uncertainties, space constraint and a penalty cost for late delivery. A joint total cost function is formulated as a constrained non-linear programming problem. The joint total cost is minimized in order to determine the optimum order quantity, reorder point and number of shipments. Solution procedures are demonstrated through complete numerical examples with different probability distributions of demand and lead time. A set of efficient and good solutions obtained are predictive of an economic operating policy for the joint contract.

## 3 - Strategic Safety Placement under Stochastic optimal Control Policy

Shunichi Ohmori, Assistant Professor, Waseda University,  
Room 0903A, Okubo 3-4-1, Shinjuku, Tokyo, Japan

Strategic safety stock placement problem is a tactical model to determine optimal places and levels of safety stocks in multi-echelon system. Existing models, such as guaranteed-service model or stochastic-service model, use the base-stock policy as a building block, under which each stage observes demand and places an order on its suppliers equal to the observed demand. In this study, we propose a safety stock placement model under stochastic optimal control policy, where order-quantity is calculated so as to minimize weighted sum of variation of inventory and order-quantity over infinite time horizon. By doing so, variation of order-quantity can be reduced as well as inventory level.

## ■ WA34

North Bldg 223

## Practice- Disaster and Disruption Management II

Contributed Session

Chair: John Doeringhaus, University of Arkansas, Fayetteville, AR, 72701, United States

## 1 - An Optimization Model for Wildfire Suppression Process and Resident Evacuation

Siqiong Zhou, San Jose State University, San Jose, CA, 95123,  
United States, Ayca Erdogan

Wildland-urban interface (WUI) wildfires have been big threats in many countries. We present a two-stage stochastic integer programming model for efficient wildfire comprehensive response on firefighting resource allocation and resident evacuation. This model minimizes the number of residents at risk and considers the total cost of resource operation and property loss. Resource preparation and allocation decisions are made based on both fire spread process and population density.

## 2 - Smart City Emergency Response Simulation Framework

Charles Njelita, Data Scientist, TATA America International Inc,  
379 Thornall Street, Edison, NJ, 08837, United States

Cities around the world are becoming smarter and one of the criteria of a smart city is its ability to evacuate its citizens and visitors in the case of natural disaster, bomb blast, highway accident etc. How fast the first responder to the scene of the incidence determines the number of lives saved and injury prevented. The purpose of the paper is to develop a simulation framework which can be used by decision makers in response to an emergency that may have impacts on multiple aspects of the urban environments and socio-economical operations. These researchers will develop a multi-level simulation framework used by decision makers in city to make timely and effective responses to an emergency.

## 3 - Simulating and Analyzing Cascading Failures in Power Networks in Disaster Aftermath

Alireza Inanlouganji, Arizona State University, 699 S. Mill Ave,  
Tempe, AZ, 85281, United States, Giulia Pedrielli

Proactive response to disasters is an increasingly interesting area of research with high potential of cost reduction and safety improvement. We propose a novel framework to efficiently simulate and quickly analyze power networks and their interactions with other critical interdependent infrastructures. Both initial, exogenous, failures and failures due to cascading effects are considered and we seek a set of interesting scenarios that lead to worst adverse effects on the power network using an efficient simulation-optimization algorithm.

## 4 - Management of Interdependent Infrastructure Networks under Disaster-related Uncertainties

Tugce Canbilen, Research Assistant, Middle East Technical  
University, Universiteler Mahallesi, Dumlupinar Bulvarı No: 1,  
Endustri Myhendisligi Balumu, Ofis: 326, Ankara, 06800, Turkey,  
Sakine Batun, Melih Celik

After a disaster, multiple infrastructures have disruptions in their services. During the restoration of these services, we need to consider the operational and restoration interdependencies among these infrastructures. In this study, the problem under consideration is Interdependent Infrastructure Restoration with disaster related uncertainties. We propose a two-stage program for this problem. First stage makes reinforcement decisions on the arcs of the network while second stage schedules the restoration activities considering the available resources and inherent interdependencies in the network. We will present our computational tests and preliminary results in the presentation.

## 5 - Classification of the Interdependencies in the Food and Agriculture Critical Infrastructure in Arkansas

John Doeringhaus, University of Arkansas, 4207 Bell Engineering  
Center, Fayetteville, AR, 72701, United States, Sarah G. Nurre,  
Kelly Sullivan, Benjamin R. Runkle

Classifying infrastructure interdependencies is vital for the creation of realistic disaster preparedness and response models. The existing interdependency classifications do not capture many intricacies of the critical food and agriculture infrastructure. We propose new infrastructure interdependency classifications relevant to food and agriculture which can be generalized to many critical infrastructures. With each new classification, we provide real accounts and examples based on over 30 interviews with stakeholders in the food and agriculture critical infrastructure sector.

## ■ WA35

North Bldg 224A

## Passenger Demand Forecasting and Airline Capacity Management

Sponsored: Aviation Applications

Sponsored Session

Chair: Farbod Farhadi, Roger Williams University, 1 Old Ferry Road,  
Bristol, RI, 02809, United States

## 1 - A Modeling Framework for the Airline Near-term Capacity Adjustment Problem

Ahmed Abdelghany, Professor, Embry-Riddle Aeronautical  
University, College of Business, 600 S. Clyde Morris Boulevard,  
Daytona Beach, FL, 32114, United States, Khaled Abdelghany,  
Farshid Azadian

A modeling framework for the airline's near-term capacity adjustment problem is presented. The input to the model is an initial schedule for the host airline and any expected near-term changes in origin-destination (OD) demand, competition, and resources (aircraft, gates, etc.). The model searches for the best possible adjustments for flight frequency for each fleet type in each city-pair to maximize profitability. The performance of the framework is evaluated through several experiments in a hypothetical setting that mimics the U.S. domestic market, where the model is used to study the capacity adjustment for two major airlines.

## 2 - Flight Outsourcing in the U.S. Domestic Market

David F. Pyke, University of San Diego, Coronado 108, 5998 Alcalá  
Park, San Diego, CA, 92110-2492, United States, Farbod Farhadi,  
Soheil Sibdari

Major airlines, while maintaining route and airport dominance, outsource a portion of their services to smaller operators for a fee. Smaller operators offer their services either exclusively to a single major airline, or partner with multiple airlines within the same markets. In this research, we investigate the impact of such phenomena on total capacity and average prices.

## 3 - Passengers Demand Forecasting of the U.S. Domestic Airline Market

Nahid Jafari, Farmingdale State College, 2350 Broadhollow Road,  
Farmingdale, NY, 11735, United States

This research examines the strategies followed by the U.S. domestic airlines in 21st century to achieve their highest revenue in regard with their capacity choices. During this period, although the airlines experienced higher load factors and inflated airfares, in addition to the fluctuation of fuel expenses, they were having profit losses. The analysis is conducted on 16 major airlines on primary factors such as the load factor, market supply (seats) and demand (passengers), unemployment rate, fuel expenses, flight frequency, and aircraft size. We deploy the Long Short-Term Memory network to forecast the U.S. domestic airline passengers.

## ■ WA36

North Bldg 224B

### Joint Session Drones/Practice Curated: Drone Applications in Healthcare

Emerging Topic: Robotics, Drones and Autonomous Vehicles in Logistics

Emerging Topic Session

Chair: Justin James Boutilier, University of Toronto, Toronto, ON, M6G 2P5, Canada

#### 1 - Response Time Optimization with Queuing Constraints for Drone Delivered Defibrillators

Justin James Boutilier, University of Toronto, Toronto, ON, M6G 2P5, Canada, Timothy Chan

Out-of-hospital cardiac arrest (OHCA) is a time-sensitive medical emergency claiming over 400,000 lives each year and an automated external defibrillator (AED) is one of the only effective methods for treating OHCA. In this paper, we propose an integrated location-queuing model to minimize the total number of drones required to meet an average response time goal while guaranteeing a sufficient number of drones are located at each base. We develop a novel reformulation technique that allows us to solve real-world instances and determine the optimal deployment of AED-enabled drone resources using eight years of data covering 26,000 square kilometers around Toronto, Canada.

#### 2 - Drone-aided Healthcare Services for Patients with Chronic Diseases in Rural Areas

Gino Lim, University of Houston, Professor and Chairman, Dept of Industrial Engineering, Houston, TX, 77204, United States, Seon Jin Kim

We present the drone-aided delivery and pickup planning of medication and test kits for patients with chronic diseases in rural areas. A two-stage decision model is proposed to find the optimal number of drone center locations and schedule pickup and delivery in which drones deliver medicine to patients and pick up exam kits on the way back such as blood and urine samples. A preprocessing algorithm, a Partition method, and a Lagrangian Relaxation (LR) method are developed to solve the model. A cost-benefit analysis method is developed as a tool to analyze the benefits of drone-aided healthcare service.

#### 3 - Cure for Healthcare Using Drone Technology in Hospital Processes an Explorative Analysis

Mike Krey, Zurich University of Applied Sciences, Winterthur, Switzerland

The paper at hand aims at outlining the potential and possible fields of application using drone technology inside the Swiss hospital environment. As part of a survey, face-to-face interviews with IT executives of four Swiss hospitals were conducted on the status quo of drone technology providing valuable insights about the current situation and the possible fields of application. The study revealed that different priorities, lack of motivation, and budget constraints were mentioned as the three major obstacles to improving the situation.

#### 4 - A Framework for Using Drones after a Tornado

Sean Grogan, PhD Candidate, École Polytechnique de Montréal, 2500 Edouard Monpetit, 2900 Chemin Polytechnique Office C314.6, Montreal, QC, H3T 1J4, Canada, Robert Pellerin, Michel Gamache

Recent innovations and advancements in unmanned aerial vehicles (UAVs) have increased their utility while reducing the cost of the devices. UAVs in the aftermath of a disaster have an obvious utility where they can fly over a search area rather than be subject to potential road blocks and other impediments. To allocate the UAVs in the aftermath of a tornado has the potential to incorporate weather information and predictions from the National Weather Service, sighting information from spotters and the media, and geographic information system information to allocate UAV resources and, in turn, rescuer resources.

## ■ WA37

North Bldg 225A

### Advances in Approximate Dynamic Programming

Sponsored: Applied Probability

Sponsored Session

Chair: David Brown, Duke University, Durham, NC, 27708, United States

#### 1 - On the Taylor Expansion of Value Functions

Itai Gurvich, Cornell University, 2 W. Loop Rd, New York, NY, 10044, United States, Anton Braverman, Junfei Huang

We introduce a framework for approximate dynamic programming that we apply to discrete time and space chains. Simply put, our approach stipulates applying Taylor expansion to the value function in the Bellman equation to obtain an

optimality equation in continuous space and time. In cases where the "Taylor-ed" equation is tractable, it provides a useful modeling tool coupled with explicit optimality-gap bounds. Computationally, our framework leads to an "aggregation" approach with performance guarantees. While the guarantees are grounded in PDE theory, the practical use of this approach requires no knowledge of such theory.

#### 2 - Interpretable Optimal Stopping

Velibor Misić, UCLA Anderson School of Management, 110 Westwood Plaza, Suite B406, Los Angeles, CA, 90095, United States, Florin Ciocan

Optimal stopping is the problem of deciding when to stop a stochastic system to obtain the greatest reward. State of the art methods for this problem rely on obtaining an approximate value function for use within a greedy policy. However, such policies are generally not interpretable, in that it is often difficult to see how the policy maps each system state to a decision. We propose a new data-driven method for optimal stopping that directly learns interpretable policies in the form of binary trees. We apply our approach to a canonical option pricing problem and show that it quickly obtains interpretable policies that outperform existing non-interpretable policies based on simulation-regression.

#### 3 - Dynamic Credit-collections Optimization

Naveed Chehraz, McCombs School of Business, 2110 Speedway, Stop B6000, Austin, TX, 78712, United States, Peter W. Glynn, Thomas A. Weber

Based on a dynamic model of the stochastic repayment behavior exhibited by delinquent credit-card accounts in the form of a self-exciting point process, a bank can control the arrival intensity of repayments using costly account-treatment actions. A semi-analytic solution to the corresponding stochastic optimal control problem is obtained. For a linear cost of treatment effort, the optimal policy in the two-dimensional (intensity, balance)-space is described by the frontier of a convex action region. The unique optimal policy significantly reduces a bank's loss given default and concentrates the collection effort onto the best possible actions at the best possible times.

#### 4 - Dynamic Pricing of Scarce and Relocating Resources in Large Networks

Chen Chen, Duke University, Santiago Balseiro, David Brown

We study dynamic pricing of resources distributed over a network of locations (e.g., shared vehicle systems). Customers with private willingness-to-pay sequentially request to relocate one resource. We focus on networks with a hub-and-spokes structure. We develop a dynamic pricing policy based on a Lagrangian decomposition and show that the policy is asymptotically optimal as the number of spokes grows large but the number of resources per location remains fixed.

## ■ WA38

North Bldg 225B

### Dynamic Queueing Control

Sponsored: Applied Probability

Sponsored Session

Chair: Mark E. Lewis, Cornell University, Ithaca, NY, 14853, United States

#### 1 - Dynamic Control of Running Servers

Douglas Down, McMaster University, Department of Computing and Software, 1280 Main Street West, Hamilton, ON, L8S 4K1, Canada, Esa Hyytiä, Pasi Lassila, Samuli Aalto

Motivated by a data center setting, we study the problem of joint dispatching and server sleep state control in a system consisting of two queues in parallel. Using the theory of Markov decision processes and a novel lookahead approach, we explicitly determine near-optimal control policies that minimize a combination of QoE costs, energy costs, and wear and tear costs due to switching. Guidelines are provided as to when these combined policies are most effective.

#### 2 - Server Collaboration in Queueing Systems: When and How?

Junqi Hu, Georgia Institute of Technology, Atlanta, GA, United States, Sigrun Andradottir, Hayriye Ayhan

Consider a form of server collaboration where each job is decomposed into subtasks, and the job is finished when all its subtasks are completed. We identify the task assignment policy that maximizes the long-run average throughput for one station when servers are either static, flexible, or collaborative and internal buffers are either finite or infinite. Then we compare this model with other forms of server collaboration to determine when and how servers should collaborate. Finally, we investigate server collaboration for longer lines, and provide numerical results for two tandem stations.

### 3 - Assigning Priorities (or Not) in Service Systems with Nonlinear Waiting Costs

Nilay Argon, PhD, University of North Carolina, Chapel Hill, NC, United States, Huiyin Ouyang, Serhan Ziya

For a single-server queueing system with two types of customers and nonlinear waiting costs, we compare static queueing rules that use information on customers' types and order of arrival. Our main theorem ranks the type-based priority policies and first-come-first-serve rule according to their long-run average waiting costs under general cost functions. We then apply this result to polynomial cost functions to generate insights into when static prioritization is advantageous and when it is beneficial to consider state-dependent priority policies.

### 4 - Optimal Control Policies for an M/M/1 Queue with a Removable Server and Dynamic Service Rates

Pamela Badian-Pessot, Cornell University, Ithaca, NY, 14850, United States, Mark E. Lewis, Douglas Down

We consider an M/M/1 queue with a removable server that dynamically chooses one of two service rates. If the server is off, the system must warm up for a random, exponential amount of time, before it can begin processing jobs. We show under the average cost criterion, that work conserving policies are optimal. We then demonstrate the optimal policy can be characterized by two thresholds, one for turning on the server and another for the service rate. Finally, we explore the implications of such policies for system design.

## ■ WA39

North Bldg 226A

### Queueing Models for Healthcare Systems

Sponsored: Applied Probability

Sponsored Session

Chair: Ohad Perry, Northwestern University, Evanston, IL, 60208, United States

#### 1 - Run-through Experiments for Queues

Harsha Honnappa, Purdue, Anna Tata

We develop a simulation and theoretical framework for selecting a fitted traffic model for a queueing system. Given a dataset of inter-arrival times that displays time-of-day effects, it is often the case that a modeler wishes to fit a non-homogeneous Poisson process to this dataset. The main question we address in this talk is how to select appropriate time-buckets to aggregate the arrivals in order to fit the Poisson model, by using a simulation estimate of an appropriate performance metric as a measure of 'goodness of fit.'

#### 2 - Efficiently Selecting Arrival Models

Zeyu Zheng, Stanford University, Stanford, CA, 94305, United States

In modeling non-stationary and time-inhomogeneous data, a standard approach is to break the time horizon into multiple intervals, and then to fit a piecewise model. We propose a principled maximum likelihood approach that includes efficient model fitting, optimal interval boundary selection, and selection of model degree.

#### 3 - Optimal Scheduling in Presence of Proactive Care

Yue Hu, Columbia University, New York, NY, 10027, United States, Carri Chan, Jing Dong

Healthcare is a limited resource environment where capacity is often reserved for needy patients. A new trend in medicine is the use of preventative care models that treat patients early to eliminate the need for more expensive resource later. We study the optimal scheduling policy for a two-class multi-server queueing model to understand how patients should be prioritized for care when preventative care is an option. We study both the transient system dynamics and the steady-state performance. In the first case, we analyze the most cost effective way to bring the system back to equilibrium when it is started far from "normal operation". In the second case, we minimize the long-run average holding cost.

#### 4 - A Fluid Diffusion Hybrid Limit for Service Systems with Fast and Slow Customers

Lun Yu, Northwestern University, Evanston, IL, 60208, United States

Motivated by emergency departments, we consider a queueing system with two customer classes; the first class (of "high acuity") requires long service times and receives priority over the second class ("low acuity"), whose average service times are substantially shorter. Unfortunately, the dynamics of such a system are intractable, and existing heavy-traffic regimes cannot capture the fact that, in practice, a non-negligible proportion of the arrivals from either class must wait for service. We propose a Fluid-Diffusion Hybrid limit to approximate the two queues, and demonstrate how it can be employed to study the benefits of de-pooling (namely, of having a "fast-track").

## ■ WA40

North Bldg 226B

### Decision Analysis and Research Study Design

Sponsored: Decision Analysis

Sponsored Session

Chair: Saurabh Bansal, Penn State University, State College, PA, 16801, United States

#### 1 - Qualitative Not as Lesser Than: Guidelines for Deciding Between a Qualitative and Quantitative Decision Approach

Kara M. Morgan, Quant Policy Strategies, LLC, 8375 Nemain Loop, Dublin, OH, 43016, United States

In practice, decision methodologies can drive decisions, and biases against using qualitative methods can limit the options considered by decision analysts. There is a common conception that qualitative research is more appropriate for exploratory research rather than for informing decision making. In fact, there are many general cases in which taking a quantitative approach can obscure the issues and therefore reduce the potential impact of decision analysis on the decision. This talk will identify conditions under which qualitative methods could lead to better decisions and provide pointers for utilizing rigorous qualitative methods for decision making support.

#### 2 - Research Methodologies and the Field of Decision Analysis

Jeffrey M. Keisler, University of Massachusetts-Boston, M/5 249, 100 Morrissey Boulevard, Boston, MA, 02125, United States

This presentation considers three questions. (1) What is a research methodology as opposed to any old methodology and what is the role of research methodologies in scholarship? (2) In what ways do and in what ways can decision analysis scholars incorporate common research methodologies? (3) How and why might we think of decision analysis itself as a research methodology?

#### 3 - Accelerating Learning using Expert Judgment about the Relationship between Model and Reality

Eva D. Regnier, Naval Postgraduate School, 555 Dyer Road, Bldg. 330, Room 287, Monterey, CA, 93943, United States, Melissa A. Kenney, Michael Gerst

Because of their power to influence decisions, it's useful to consider how the modeling process can be improved by formalizing the role of expert judgments in building, validating, and interpreting models. Bayesian reasoning - asking what model output we ought to expect as a function of the possible states of the modeled system - is rarely applied in mechanistic (vs. statistical) models. By formalizing expert judgments regarding the joint relationship between reality and model output, our framework (i) suggests new questions that should be asked in the model building and validation process and (ii) guides how model outputs should be interpreted, resulting in higher-value models and inferences.

#### 4 - Using Software to Help Engage with Clients

Max Henrion, Lumina Decision Systems, Inc, Campbell, CA, United States

We will share experience on how decision analysts can use software tools to facilitate understanding and analyzing new problems, by using influence diagrams to frame and bound decision problems, an agile modeling process driven by interactive sensitivity analysis, and model exploration and visualization to help clients get a visceral understanding of how decisions affect the objectives they care about.

## ■ WA41

North Bldg 226C

### DA Arcade I

Sponsored: Decision Analysis

Sponsored Session

Chair: William Nicholas Caballero, Air Force Institute of Technology, 6465 Hemingway Road, Dayton, OH, 45424, United States

#### 1 - Valuation of Strategic Adaptation

Byunghee Choi, Penn State University, University Park, PA, United States, Robert D. Weaver

We introduce a continuous time economic model of multiple stage processes with fixed stage commitment. Stage-based commitment is made within the context dynamic evolution of uncertainty with respect to process performance. Within this context, we introduce a method for valuation of strategic adaptation to change in uncertainty and information evolution. We illustrate our approach with simulation.



## 2 - Coordinating Decisions in Decentralized Perishable-products Supply Chains via Contracts

Sandra Transchel, Kuehne Logistics University, Grosser Grasbrook 17, Hamburg, 20457, Germany

We consider a two-stage supply chain consisting of a vendor and buyer selling a perishable product, more specifically, a product with a finite life time. We investigate different contracts and their impact on both the vendor's and the buyer's inventory decision in a decentralized decision-making environment. Beside the wholesale price, the contracts specify the minimum residual shelf life the buyer is willing to accept as well as a service level agreement and penalty payments. We compare the decentralized solution with the inventory policy of a centralized decision-maker and show the impact on the supply chains profitability and waste performance.

## 3 - Head Against the Wall: The Connection between Concussions and Overconfidence

Dominik Piehlmaier, Dissertator in Consumer Behavior, University of Wisconsin-Madison, Madison, WI, 53703, United States

An estimated average of 3.8 million concussions occur every year within the US. However, only approximately half of all cases are reported (Harmon et al., 2013). This study sheds light on the influence of overconfidence on the propensity to experience a concussion and on the likelihood to report it. Data drawn from survey responses from around 1,000 athletes were used to analyze these aspects. A set of Bayesian regressions and Bayesian structural models, using an efficient Hamiltonian Monte Carlo sampler, was fitted to analyze the data. The results suggest that athletes who are overconfident in their ability to detect a concussion, are more likely to experience one but are less likely to report it.

## 4 - Influence Modeling: Mathematical Programming Representations of Persuasion under Either Risk or Uncertainty

William Nicholas Caballero, Air Force Institute of Technology, 6465 Hemingway Road, Dayton, OH, 45424, United States, Brian J. Lunday

Persuasion is a fundamental element of human interaction applied to both individuals and populations. Although the study of persuasion has historically been dominated by qualitative models, this research advances its quantitative characterization and future use. This research complements the qualitative psychological literature with respect to the processing of persuasive messages by developing an influence campaign design framework. We adapt the classic Decision Analysis problem to a bilevel mathematical program, wherein a persuader has the opportunity to affect the environment prior to the decisionmaker's choice. Thereby, we define a new class of problems for modeling persuasion.

## 5 - When Payoffs Look Like Probabilities: Separating Form and Content in Risky Choice

Johannes Müller-Trede, IESE Business School, Barcelona, Spain, Shlomi Sher, Craig R. McKenzie

Prospect theory assumes a value function that is concave for gains and convex for losses, and an inverse S-shaped probability weighting function. But in typical studies, form and content are confounded: Probabilities are represented on a bounded scale, whereas representations of gains (losses) are unbounded above (below). To unconfound form and content, we ran studies employing a probability-like representation of outcomes and an outcome-like representation of probability. We show that interchanging numerical representations can interchange the resulting psychophysical functions. Traditional models may reflect subjective reactions to numerical form rather than substantive content.

## ■ WA42

North Bldg 227A

### Simulation and Optimization

Contributed Session

Chair: Harri K. Ehtamo, Aalto University, P.O. Box 1100, FIN-02015 HUT, Espoo, 02150, Finland

## 1 - Modeling Systematic Technology Adoption with Heterogeneous Interacting Agents

Huayi Chen, Nanjing University of Aeronautics and Astronautics, 29 Yudao street, Nanjing, 210016, China

Traditional systematic technology adoption models often assume one representative agent. However, researchers have been arguing that even a well calibrated representative agent cannot represent heterogeneous agents due to several reasons, of which one, is that there could be no trade. This paper intends to build a systematic optimization model of technology adoption with heterogeneous interacting agents. Agents are cost minimizing entities and the interaction among them could be the trade in goods, new advanced technology,

and further, in carbon emission credits.

## 2 - An Analysis of Overlapping Appointments in Outpatient Oncology Centers

Melissa Marquez, Binghamton University, New York, NY, 10033, United States

This research proposes a simulation-based optimization approach to minimize the total cost by considering appointment overlapping for chemotherapy scheduling in outpatient oncology centers (OOC). The model considers waiting time, chair idle time, and total clinic overtime, uses on-line Best Fit bin packing heuristic, and optimizes pre-treatment and infusion duration. The model considers uncertainties such as patient no-shows, patient tardiness, and variability in scheduled infusion duration and processing times. The appointment overlapping with efficient scheduling increases infusion chair utilization, and reduces total cost in OOC with high no-show rates.

## 3 - A Surrogate-based Tabu Search Heuristic to Optimise the People Flows in a Timetable

Hendrik Vermuyten, KU Leuven, Warmoesberg 26, Brussel, 2800, Belgium, Jeroen Belien, Liesje De Boeck, Tony Wauters

In this work, we address the problem of minimizing people flows that are the result of timetabling decisions. We assume that each event has already been assigned to a certain timeslot and we only take the decision of assigning events to rooms into account. The crowd dynamics are modelled by Menge, which is an open source microscopic pedestrian simulator, and tabu search is used to iteratively find improved solutions. To speed up the computations, a surrogate model is used that approximates the real objective function values of candidate solutions and is computationally much less costly.

## 4 - Optimizing People Flow and Safety in Buildings

Harri Ehtamo, Professor, Aalto University, P.O. Box 11100, 00076 Aalto, Espoo, 02150, Finland, Juha-Matti Kuusinen, Janne Sorsa, Marja-Liisa Siikonen, Henri Hakonen

We discuss some key advances in people flow and building safety modeling based on several years of collaborative research carried out by KONE Corporation, one of the global leaders in the elevator and escalator industry, and Systems Analysis Laboratory of the AALTO University. The talk is partly based on our OR/MS Today, April 2017, article on the subject.

## ■ WA43

North Bldg 227B

### Stochastic Optimization I

Contributed Session

Chair: Cheng-Yu Rao, Shanghai St., Taitung County 950, New Taipei City, 95048, Taiwan

## 1 - Stochastic Integer Programming Formulation for Process Discovery

Georges Spyrides, Student, PUC-Rio, Rua Marques de Sao Vicente 225 - Gávea, Rio de Janeiro, 22451900, Brazil, Marcus V. Poggi

Process discovery algorithms try to build meaningful Petri-nets from a log of events. Bergeth (2008) proposes that candidates for Petri-net places are related as basic solutions on an ILP formulation. Van Der Werf et al (2009) proposed a general method called ILP Miner. This method generates fully replayable Petri-nets, but with a downside of producing hard to understand process models in practice. This work aims to address the simplicity problem by interpreting the frequency of a sequence of events as the probability of materialization in the future. We propose a novel two stage stochastic formulation with chance constraints, which produces models not so sensitive to outlier process variants.

## 2 - A Long-term Analysis of Renewable-dominated Regions: A Stochastic Co-optimization of Expansion Planning and Dynamic Probabilistic Reserve

Alessandro Soares, Engineer, PSR, Praia de Botafogo 228, Rio de Janeiro, Brazil

As consequence of the variability in the renewable generation, system reserve requirement must be increased to maintain security and thermal units may need to operate outside their efficient operation point. Since thermal flexibility and reserve may result in substantial costs to the system, expansion planning models need to consider these costs and co-optimize them along with the expansion. We present a Multiscale Stochastic Optimization approach to optimize dynamic probabilistic reserves (DPR) and system flexibility costs due to high renewable penetration. A real-case study of the Chilean system will be analyzed to illustrate the methodology.

### 3 - Q-learning Applied to Multistage Generation Expansion Planning

Vijay Kumar, PhD Candidate, Pennsylvania State University, State College, PA, 16801, United States, Mort Webster, Uday Shanbhag

Generation expansion planning is a multi-stage decision about the technology, size and the timing for new electricity generators under uncertainty in future technical and economic uncertainties. The dynamic programming formulation for a time horizon of 10-50 years faces the Curse of Dimensionality and is computationally intractable. We demonstrate a novel adaptive sampling algorithm within a Q-Learning framework applied to multistage expansion under uncertainties in fuel prices and carbon limits.

### 4 - Solving Appointment Scheduling and Staffing Problem in Radiotherapy by Progressive Hedging Algorithm

Cheng-Yu Rao, National Chiao Tung University, Hsinchu, Taiwan, Yu-Jyun Tang, Sheng-I Chen

A two-stage integer stochastic programming model for appointment scheduling and staffing decisions in a radiotherapy department is developed. The treatment start and staff assignment are determined in the first stage, and the number of treatments and overtimes are decided in the second stage. A scenario decomposition scheme, along with the implementation of progressive hedging algorithm is presented. The computational experiment investigates different penalty settings for nonanticipative decisions. The convergence of the algorithm has been shown despite of oscillatory behavior is observed. We report the solution quality and runtime for general branch-and-bound and our proposed methods.

### 5 - Capacity Optimization for Innovating Firms

Rita Pimentel, RISE SICS Vasteras, Vasteras, Sweden  
Rita Pimentel, Cemat, Instituto Superior Técnico, Lisboa, Portugal,  
Verena Hagspiel, Kuno Huisman, Peter M. Kort, Cláudia Nunes

In case of a product innovation the firms start producing a new product. While doing so, they should decide what to do with their existing production process. They can choose between replacing the established production process by the new one, or keep on producing the established product so that they produce two products at the same time. Due to technological progress, the quality of the newest available technology increases over time. So, the firms face the tradeoff between innovating fast that enlarges the payoff soon but only by a small amount, or innovating later that leads to a larger payoff increase, the drawback being that they are stuck with producing the established product for a longer time.

## ■ WA44

North Bldg 227C

### Real-time Optimization in Power Systems

Sponsored: Energy, Natural Res & the Environment/Electricity

Sponsored Session

Chair: Na Li, Harvard University, Cambridge, MA, 02138, United States

Co-Chair: Hao Zhu, The University of Texas at Austin, Austin, TX, 78712, United States

#### 1 - Real-time Resilient Operation of Multi-microgrid Networks

Amin Gholami, Georgia Institute of Technology, Atlanta, GA, United States, Andy Sun

Although microgrids pave the way for integrating various distributed energy resources, they raise many challenges. Emergency control of dangerous transients caused by the transition between the grid-connected and island modes is one of such challenges. To address this, we propose an optimization and real-time control framework for maintaining the frequency stability of multi-microgrid networks under an islanding event. We develop a strong MISOPC-based reformulation as well as a cutting plane algorithm for scalable computation. Our framework provides the optimal load shedding and optimal topology reconfiguration, while the frequency dynamics and AC power flow limitations are considered.

#### 2 - Event Identification and Data Recovery from Highly Quantized Measurements

Meng Wang, Rensselaer Polytechnic Institute (RPI), Troy, NY, 12180, United States, Ren Wang

One can add noise and apply quantization to synchrophasor measurements to increase the data privacy and reduce the communication cost. This talk focuses on event identification and data recovery at the operators' side from the highly quantized measurements. Event identification can be achieved by solving a data clustering problem that aims to group measurements affected by the same event together. The recovery and clustering are achieved simultaneously by solving a nonconvex constrained maximum likelihood problem. A fast algorithm with the performance guarantee is proposed to solve the nonconvex problem. The proposed method is evaluated numerically on recorded synchrophasor datasets.

### 3 - Online Localization of Forced Oscillations in the Power Grid

Le Xie, Texas A&M University, College Station, TX, United States, Tong Huan, P.R. Kumar, Nickolaos M. Freris

In this talk, we will present a data-driven method to pinpoint the source of a new emerging dynamical phenomenon in the power grid, referred to "forced oscillations in the difficult but highly risky case where there is a resonance phenomenon. By exploiting the low-rank and sparse properties of PMU measurements, the localization problem is formulated as a matrix decomposition problem, which can be efficiently solved by the ALM algorithm. The data-driven nature of the proposed method allows for a very efficient implementation. The proposed method may possibly be more broadly useful in other situations for identifying the source of forced oscillations in resonant systems.

### 4 - Online Optimization with Feedback for Power Systems

Emiliano Dall'Anese, University of Colorado, Boulder, CO, United States

This talk focuses on real-time incentive-based mechanisms to coordinate distributed energy resources (DERs) with both continuous and discrete control variables. A multi-period social welfare maximization problem is formulated and, based on its convex relaxation, a distributed stochastic dual gradient algorithm is proposed. Real-time implementations involve asynchronous updates and feedback being leveraged to account for nonlinear power flows as well as to reduce communication overhead. The resulting algorithm provides a general online stochastic optimization algorithm for coordinating networked DERs with discrete.

### 5 - Second-order Decomposition ACOPF

Shenyinying Tu, Northwestern University, Evanston, IL, 60201, United States, Ermin Wei, Andreas Waechter

This project proposes an algorithm to speed up solving large scale Alternating Current Optimal Power Flow (ACOPF) problem through decomposition and parallelization. In this project, we decompose the power flow network into a meshed network and a number of radial networks, and formulate the entire ACOPF problem as a bilevel optimization problem. In the upper level meshed network, we optimize the entire network and pass the information to the lower level tree networks. Then in each of the lower level problem, we solve it exactly via its relaxed SOCP formulation. The performance of the algorithm can be improved by parallel computing of the lower level problems.

## ■ WA45

North Bldg 228A

### Practice- Energy Policy and Planning I

Contributed Session

Chair: Yanyan Ding, North China Electric Power University, Beinong road, Changping, Beijing, 102206, China

#### 1 - Resilient Based Optimal Interconnection Planning of Community Microgrids in Power Grids

Masoud Barati, Assistant Professor, University of Pittsburgh, Patrick F. Taylor Hall, Room 3325, Benedum Hall, 3700 O'Hara Street, Pittsburgh, PA, 15261, United States

We proposed a resilient planning problem of networked microgrids with DERs. We integrate the investment problem and two sets of operating problems associated with the grid-connected and islanding modes of microgrids into a two-stage stochastic model to capture randomness nature of hazard events and long-term load growth, as well as the islanding risk caused by external disturbances with a joint-chance constraint to prevent the risks. A SOCP formulation is presented to incorporate AC-OPF in short-term operation. Numerical results on distribution systems prove the effectiveness of the model.

#### 2 - An Inter-hourly Methodology for Valuation of Windfarms

Sergio Cabrales, Assistant Professor, Universidad de los Andes, Calle 19 A. no 1-37 Este, ML-325, Bogota, 111711, Colombia, Carlos Valencia, Daniela Moreno, Sebastian Toro

This paper proposes a methodology for the financial valuation of wind power generation based on an hourly estimation approach, including inter-hour velocity and energy spot market. For this purpose, we propose that the energy generation is modelled through an autoregressive copula methodology for univariate series and the spot prices are estimated as the function of two components, a deterministic seasonal pattern and a Gaussian mean-reversion process. We applied the developed methodology to a case study in La Guajira, Colombia, reinforces the idea that an inter-hour approach improves significantly the precision of the financial indicators.

### 3 - Game Theoretic Demand Side Management with a Shared Storage Device

Jinkyoo Park, Korea Advanced Institute of Science and Technology, 291 Daehak-ro, Yuseong-gu, Daejeon, 34141, Korea, Republic of, Jaeyeon Jo

In this study, we propose a decentralized control strategy for distributed energy storage units in a single shared energy storage system. In the proposed control strategy, each ESS user tries to minimize their energy cost while optimizing the charging and discharging schedule of their storage unit and, at the same time, trading their storage capacity among other users, which results in a Nash equilibrium strategy of all the ESS users. We show the derived Nash equilibrium strategy with capacity trading significantly reduces the average energy cost of users and reduces the peak load of the grid.

### 4 - A Contract Design Model for Power Demand Side Management

Lakshmi Palaparambil Dinesh, Visiting Instructor, Purdue University Fort Wayne, 2101 E. Coliseum Boulevard, Neff 340Q, Fort Wayne, IN, 46805-1445, United States

Demand Response (DR) is a mechanism of adjusting electricity usage with respect to peak demand and prices for electricity. DR helps consumers save energy as well as reduce utility bills. This paper covers a novel contract design model that combines customer preferences with utility provider cost minimization model. This novel Contract Design (CD) model has 20% cost savings compared to a benchmark model used in practice. Additionally, we use the CD model to determine the factors leading to cost savings and also identify how customer preferences affect contract design.

### 5 - Maximum Renewable Utilization with Large Number of Electric Vehicles

Pouya Sharifi, Texas A&M University, Emerging Technologies Building,, 3131 TAMU, 101 Bizzell Street, College Station, TX, 77840, United States

Vehicle to grid uses electric vehicles (EV) as distributed generation/storage devices to maintain the balance of supply and demand. However, the volatile power generation of renewable energy sources (RES) and unpredictable charging schedule of EV owners may cause problems in system scheduling and as a result, may lead to power curtailment. In this work, we propose a new scheduling framework that exploits the charging information and car owners' flexibility to build a reliable system while maximizing the RES utilization. We will simulate the proposed algorithm to check the quality of the solutions and schedules.

### 6 - Research on the Connection and Construction of Sustainable Development for Smart City and Smart Grid

Yanyan Ding, Research Assistant, North China Electric Power University, No. 2, Beining road, Changping, Beijing, 102206, China

Smart city is a new form of urban development with the deep integration of ICT technology into the urban life, and the distributed renewable energy has become an indispensable element of the sustainable development of smart cities. Smart grids, an application of ICTs, can support to connect the energy production and consumption with plenty of electronic components. This article describes the internal relationship between the construction of smart grids and the sustainable development of smart cities. It points out that building an integrated energy system with millions and thousands of self-equilibrium cells in it can serve as an effective approach for the sustainable development.

## ■ WA46

North Bldg 228B

### Operational and Planning Issues of Integrated Energy Markets

Sponsored: Energy, Natural Res & the Environment/Energy

Sponsored Session

Chair: Stefanos Delikaraoglou, ETH Zurich, Zurich, 8092, Switzerland

#### 1 - Unit Commitment for an Integrated Electricity and Gas Market

Pascal Van Hentenryck, University of Michigan, 1813 IOE Building, 1205 Beal Avenue, Ann Arbor, MI, 48108-2117, United States, Geunyeong Byeon

We consider the joint operations of the electricity and gas networks, capturing the operations of both networks and the market considerations with high fidelity. We present a mixed convex optimization programming approach to the unit commitment problems for the joint operations and compare its benefits to the practice in the field.

#### 2 - Security Assessment in Gas-electric Networks

Line Roald, University of Wisconsin-Madison, Madison, WI, United States, Conor O'Malley, Gabriela Hug

The flexibility offered by gas generation is beneficial for electric grids, particularly in the face of increasing renewable generation. However, the gas system sometimes experiences limitations in the ability to deliver gas, with potentially detrimental impacts on the electric grids. We investigate how different operational

criteria for the gas system cause different levels of post-contingency gas curtailments to generators, with different impact on electric grid operation. Our case study confirms that the security criterion used to determine the required gas curtailments has significant impact the operational cost of the electric grid.

### 3 - Optimal Short-term Operation of Combined Heat and Power Plants Using Different Operation Modes

Ignacio Blanco, Technical University of Denmark, Asmussens Alle, Bygning 303B, Kgs Lyngby, 2800, Denmark, Daniela Guericke, Juan M. Morales, Henrik Madsen, Jong-Bae Park

The optimal operation of combined heat and power plants (CHP) is a relevant approach to achieve the integration of both the power grid and the district heating network, where the latter can be used as a buffer to accommodate the fluctuation of renewable energy sources. Large combined cycle gas turbines (CCGT) and coal-based CHP plants can operate in several operation modes. Therefore, the optimal operation of these units results in a computationally hard optimization problem. We propose a stochastic MILP model that can efficiently operate large CHP units making use of the different operation modes to achieve a better co-optimization of the district heating and power networks.

### 4 - Modelling Long-term and Short-term Uncertainty in Power Market Investments

Asgeir Tomasgard, Norwegian University of Science and Technology, Dept. of industrial economics, Alfred getz vei 3, Trondheim, 7491, Norway

The EMPIRE model is a European multiscale power market model with investments towards 2050 as well as representative hours. It is well suited to capture operational uncertainty in generation from intermittent energy sources like wind and sun. In this paper we add long-term uncertainty to the formulation. This makes it possible to also study uncertain learning curves, policy uncertainty, long-term commodity process and demand trends. The resulting models are large scale stochastic multi-stage recourse models with hundred of millions of variables. We present both solution methods and analysis of the most important factors.

### 5 - Information Sharing for Independent Scheduling of Electricity and Natural Gas Systems

Stefanos Delikaraoglou, ETH Zurich, Physikstrasse 3, ETL G22, Zurich, 8092, Switzerland, Gabriela Hug

The increasing shares of gas-fired electricity generation call for improved coordination between power systems and gas networks. Ideally, these systems should be co-optimized, sharing all the necessary technical and economic information to ensure feasible operation and to minimize total system cost. However, according to the current framework, the scheduling of electricity and natural gas operations is performed through independent and nonconcurrent markets. To address this issue of partial coordination we propose an asynchronous information sharing mechanism, which allows dispatching the gas system accounting for the feasible re-dispatch actions and their cost on the electricity side.

## ■ WA48

North Bldg 229B

### Energy Policy and Planning I

Contributed Session

Chair: Fikri Kucuksayacgil, Iowa State University, 610 Squaw Creek Drive, Unit 18, Ames, IA, 50010, United States

#### 1 - Asynchronous Decentralized Solution Framework for Large Scale Unit Commitment

Paritosh Raman, Georgia Institute of Technology, Atlanta, GA, United States

The unit commitment problem for power networks is a critical and a computationally challenging problem especially for large-scale power systems. We propose an asynchronous decentralized solution to the unit commitment problem that preserves privacy of infrastructural data and is also resilient to cyber attacks. We demonstrate that our method is highly scalable, improves computational efficiency and provides a competitive and stable solution quality.

#### 2 - Enabling the Smart Grid with Power Cloud

Lida Haghnegahdar, PhD Candidate and Research Assistant, SUNY, Vestal, NY, United States, Yong Wang

Dynamic pricing, load management and responding to the demands of the energy market are some of the characteristics of a smart grid. And a reliable and cost-effective modern smart grid is desired. One way to achieve these objectives is to implement a cloud approach, where monitoring power grid data flow and data center management are key. A cloud-based approach provides a suitable environment with tools to manage and access data effectively. The objective of this paper is to introduce the power cloud model: an energy system model based on enabling accessible service to computing resources, real-time data stream processing and an environment to integrate data sharing.



### 3 - Valuation of Long-duration Grid Energy Storage using Production Cost Models

Jiazi Zhang, Postdoctoral Researcher - Electrical Engineering, National Renewable Energy Laboratory, 15013 Denver West Parkway, Golden, CO, 80401, United States, Joshua Eichman, Omar Jose Guerra Fernandez

The integration of high shares of variable renewable energies raises challenges for the reliability and cost-effectiveness of power systems. Long-duration storage is one of the most promising options to solve these problems. In this study, the system-level impacts of long-duration storage on the Western Interconnect (WI) power system will be explored. The operations of future WI with 50%, 70%, and 90% renewable penetration are simulated using a production cost modeling tool - PLEXOS. The net system benefits of different storage and demand response technologies are assessed including pumped hydro, compressed air energy storage, flow batteries, power-to-gas, and power-to-gas-to-power.

### 4 - Electric Generation Investment under Uncertainty: Applying Decision Analysis to a Complex Electric Power Systems Model

David Young, EPRI, Palo Alto, CA, 94304, United States, Nidhi Santen

We adapt the deterministic US-REGEN inter-temporal capacity expansion model to approximate a stochastic model by wrapping it within a decision tree framework. We apply this framework to study how the anticipation of future climate policy or natural gas price shocks in the U.S. impacts generation investment decisions ex-ante. We find investing in new wind/solar or gas-fired units is generally robust to a range of futures, but investing in new nuclear units or units with carbon capture and storage prior to the shock may lead to high regretted costs.

### 5 - Performance Evaluation in Distributed Photovoltaic Systems Using Data Envelopment Analysis

Adiel Teixeira De Almeida Filho, Universidade Federal de Pernambuco, Caixa Postal 7471, Av. General San Martin, 1083, Recife-PE, 50.630-971, Brazil, Ivaro Cavalcanti, Francisco de Assis dos Santos Neves, Gustavo Medeiros Azevedo

This paper uses the Data Envelopment Analysis (DEA) technique to verify the performance of micro- and mini-generation systems in order to reveal the best practices that could be observed so that these may be replicated in order to justify the increase in photovoltaic generation in this type of system that will be distributed and managed by the population. During the analysis, data were collected on 123 micro- and mini-generation units distributed in an area of 98.5 km<sup>2</sup> in the Northeast region of Brazil.

### 6 - A Lattice Method for Jump-diffusion Process Applied to Transmission Expansion Investments under Demand and Distributed Generation Uncertainties

Fikri Kucukayacigil, Iowa State University, Ames, IA, 50010, United States, K. Jo Min

In recent years, decision makers of expansion investments in transmission sector have faced critical uncertainties such as growth of demand for electricity and installation of distributed generations (DGs) owned by customers. Power lines should be expanded strategically as installation of DGs may create stranded costs for transmission owners as they meet a portion of local demand. We develop a computationally efficient lattice method to model uncertainties in the form of geometric Brownian motion and compound Poisson process. We propose a real options framework which quantifies the value of expansion investments. Proposed framework is demonstrated on a hypothetical example.

## ■ WA49

North Bldg 230

### Practice- Game Theory II

Contributed Session

Chair: Patanjali Kumar, Indian Institute of Management Rohtak, MDU Campus, Everest Hostel, Rohtak, 124001, India

#### 1 - A Decentralized Algorithm for Finding Nash Equilibrium under Imperfect and Incomplete Information

Kyuree Ahn, KAIST, Daejeon, Korea, Republic of, Jinkyoo Park

In this study, we propose a nonparametric decentralized algorithm to find a Nash equilibrium of a repeated game with imperfect and incomplete information. At each iteration of the game, each player executes his own action and observes the reward and other players' executed actions (strategies). Each player then updates his belief both on his own reward function and on other players' joint strategy using Gaussian Process Regression and Log Gaussian Cox Process, respectively. As each player best responds to their beliefs that is being updated, the joint of individually updated strategy converges to a Nash equilibrium in a distributed way.

#### 2 - Socially Differentiated Products: A Game Theoretic Approach

Hannan Sadjady Naeeni, University of Houston, Houston, TX, United States, Powell Robinson

We propose a game-theoretic duopoly model to identify equilibria configurations where one, none, or both of the firms offer socially responsible (SR) products. Our analysis shows how firms' commitment to socially responsible products depends on the marginal cost differences, market growth, and changes in consumer's perception of brand.

#### 3 - Information Aggregation via Rational Learning in Imperfect Information Routing Games

Manxi Wu, Massachusetts Institute of Technology, Cambridge, MA, 02142, United States, Saurabh Amin, Asuman Ozdaglar

We study rational learning dynamics in traffic routing games when travelers have imperfect information about an unknown network state. In each stage, travelers myopically choose routes based on their current belief distribution, and noisy realizations of travel costs on the chosen routes become publicly available. We show that rational learning can lead to a self-confirming equilibrium in which average traveler cost is higher than the cost under full knowledge of the state. We specialize our results in situations in which self-confirming equilibrium does not exhibit such informational inefficiency, i.e., travelers make route choice as if they have complete information about the state.

#### 4 - Using Auditing and Commitment for Engaging a Supplier for Supply Chain Sustainability

Hossein Rikhtehgar Berenji, PhD Candidate, University of Oregon, Lundquist College of Business, 1208 University of Oregon, Eugene, OR, 97403-1208, United States, Nagesh N. Murthy, Zhibin Yang

We model a buyer auditing a supplier for sustainable business practices. We investigate the effect of buyer's upfront commitment to price and quantity on supplier's compliance with the code of conduct and buyer's auditing effort and supply chain sustainability. We analyze implications of raising the standard of code of conduct on sustainability and financial performance.

#### 5 - Impact of Virtual Organization in Sustainable Supply Chain Contracts

Patanjali Kumar, Indian Institute of Management Rohtak, MDU Campus, Everest Hostel, Rohtak, 124001, India, Peeyush Pandey, Gourav Dwivedi

This paper presents a novel approach to coordinate green and socially responsible supply chain using contracts. We compare the traditional and virtually integrated form of an organization using game theoretic approach. Through numerical examples, we demonstrate the effectiveness of our models. Our results reveal that virtual organization performs better than the traditional form of an organization under specific conditions.

## ■ WA50

North Bldg 231A

### Practice- Retail Management II

Contributed Session

Chair: Wenli Peng, Katholieke Universiteit Leuven, Voie du Roman Pays 34 bte L1.03.01, Louvain la Neuve, 1348, Belgium

#### 1 - Win the Buy Box - Reselling or Marketplace

Hao Su, University of Maryland-College Park, 3330 Van Munching Hall, College Park, MD, 20742, United States, Laharish Guntuka, Martin E. Dresner

This paper examines an internet retailer's decision to directly sell a product. The internet retailer offers customers both direct sales and sales through a marketplace. Using empirical analysis, we determine product characteristics that predict the internet retailer's decision to directly sell a product. We hypothesize that the internet retailer is more likely to sell (1) popular (vs. unpopular) products and (2) the products that have large (vs. limited) spillovers onto other products. Findings provide implications to marketplace sellers seeking to avoid direct competition with the internet retailer.

#### 2 - An Investigation of Multi-staged, Dual-pronged Order Fulfillment in E-commerce Marketplace

Hyun Seok (Huck) Lee, Assistant Professor, College of Business, Oregon State University, 3007 NW Morning Glory Drive, Corvallis, OR, 97330, United States, Yusoon Kim, Junbo Son

Increasingly large e-commerce marketplaces bring order fulfillment function in-house. As a result, we observe two internal fulfillment systems: conventional fulfillment by individual merchants (FBM) and emerging fulfillment by e-commerce platform (FBP). And they compete internally over efficiency. In this research, based on real-world e-commerce data on transactions and logistics, we compare the two internal fulfillment systems through uncovering distinctive mechanisms driving different operational and logistical decisions. By doing so, we suggest contingent conditions for moving towards the FBP option.

### 3 - Coalition Analysis of Basic Hierarchical Graph Model in Solving Climate Change Disputes

Shawei He, Assistant Professor, Nanjing University of Aeronautics and Astronautics, Nanjing, China

Coalition in hierarchical conflicts is studied in basic hierarchical graph model (BHGM). A BHGM consists of two local graph models (LGMs), containing a common decision maker (CDM) in both LGMs and two local decision makers (LDMs), each of which plays in one LGM. Coalition between CDM and an LDM, and between two LDMs, are discussed. Theorems indicate that transition from an equilibrium to another only takes place jointly by CDM and an LDM. An example of disputes over achieving emission goals between the national and provincial governments in China are investigated, suggesting that agreements on achieving stricter emission goals by a province can be reached if being subsidized by the national government.

### 4 - Cost of Information Sharing Under Group Purchasing

Wenli Peng, Université Catholique de Louvain, Voie du Roman Pays 34 bte L1.03.01, Louvain La Neuve, 1348, Belgium, Gilles Merckx, Philippe Chevalier, Aadhaar Chaturvedi

This paper investigates how information sharing dimension affects OEMs' motivations towards group purchasing, specifically in industries characterized by market demand and technology level uncertainties. Under Cournot competition, we find that group purchasing is preferred by OEMs when product technology strongly affects market demand, and that preference for group purchasing would depend on product substitutability, market demand variability and supplier rebate when influence of the product technology is low. We further find that group purchasing can benefit both the OEMs and the consumers.

## ■ WA51

North Bldg 231B

### Production & Scheduling

Contributed Session

Chair: Elham Taghizadeh, Wayne State University, 23794 Saravilla Dr, Detroit, MI, 48035, United States

### 1 - A Mixed Integer Linear Programming Formulation for Permutation Flowshop Lot Streaming Problems

Ramakrishna Govindu, University of South Florida, 8350 N. Tamiami Tr, Sarasota, FL, 34243, United States, Anurag Agarwal

MxN flowshop problems are known to be NP-hard. Lot streaming problems, being more complex than flowshop problems, are typically solved using heuristics and meta-heuristics. It is a well-known fact that problem formulations play a crucial role determining in solution times for integer and mixed integer programming problems. Given the computational power and advanced solvers available these days, is there any value in solving lot streaming as an MILP problem? We propose an MILP formulation, conduct experiments, and present the results.

### 2 - The Cutting Stock Problem with Diameter Conversion in Construction Industry

Deniz Altinpulluk, Baskent University, Ankara, Turkey, Haldun Sural

One-dimensional cutting stock problem has been widely used for reinforcement rebar steel in the construction industry. Diameter size of a rebar is determined by structural designer to provide tensile strength to the structure and it can be changed if cross-section area per concrete area stays constant. We study the problem that decides diameter size and required number of rebar providing tensile strength and cutting patterns to minimize usage of raw material. It differs from classical cutting stock as it is not known how many pieces should be cut until diameter sizes are chosen. We propose a Reflect Arc-Flow Formulation to solve the problem and provide our computational results.

### 3 - Integrated Production Planning and Scheduling in the Multistage Production System with Dynamic Forecast Updates

Hakeem-Ur Rehman, Shanghai Jiao Tong University, Shanghai, 54000, China, Guohua Wan, Zhan Yang

We study the multilevel multistage lot sizing and scheduling problem with demand information updating. We employ the Martingale Model for Forecast Evolution to model the evolving demand over the time with demand information updating and build a shortfall-based chance constraints MIP model using hybrid period approach. To solve the problem, three heuristic algorithms based on the relax-and-fix method within rolling horizon framework are developed. The results of the computational experiments show that Heuristic 1 performs better than Heuristic 2 and 3 for all the problem instances.

### 4 - Integrated Optimization of Production Scheduling and Preventive Maintenance Planning In the Flexible Job Shop.

Baoru Zhou, Tsinghua University, Beijing, 100084, China, Changchun Liu, Li Zheng

This study addresses the problem of integrating production scheduling and preventive maintenance planning in the flexible job shop. A model aimed to minimize the total tardiness is formulated. To solve the model, we propose a heuristic and an adapted Genetic Algorithm. Finally, extensive numerical experiments are conducted to test the performance of the proposed methods.

### 5 - A Biobjective Production Planning and Scheduling Model Dealing with Reworking the Perishable Items in a Parallel Machine System

Elham Taghizadeh, Wayne State University, Detroit, MI, 48035, United States, Farshid Evazabadian, Setareh Torabzadeh, Abdollah Mohammadi

Production systems could struggle with defective products due to human error, machine break-down, and imperfect production system. Reworking is one strategy to deal with this issue. Rework planning involves the production planning and scheduling of the defected items along the master production planning. This paper presents a multi-objective mathematical model to determine how the work and rework must be scheduled in a parallel machine system for perishable products. The model objective functions are the Min of cost and makespan. A linear model is developed and numerical experiments are based on a case study from the literature for biopharmaceutical industry.

## ■ WA52

North Bldg 231C

### Practice – Integer Programming & Applications I

Contributed Session

Chair: Reed Harder, Dartmouth, 14 Engineering Drive, Hanover, NH, 03755, United States

### 1 - Least Cost Energy Optimization: Pakistan Power Sector Analysis

Raza Ali Rafique, Assistant Professor, Lahore University of Management Sciences, Sector 'U', DHA, Lahore Cantt., Lahore, 54792, Pakistan

In our study, the optimal energy-mix for power generation is sought. We propose a mixed integer linear programming (MILP) model for minimizing the power generation infrastructure cost considering indigenous energy resources of Pakistan. The proposed optimization tool can assist policy makers for strategic planning and development of future energy-mix for power generation in Pakistan.

### 2 - A Weighting Local Search Algorithm for the Constrained Binary Quadratic Program

Ryutaro Matsumoto, Osaka University, Osaka, Japan, Shunji Umetani, Hiroshi Morita

We develop a 2-flip neighborhood local search algorithm for the constrained binary quadratic program (CBQP) that incorporates an incremental evaluation of solutions and an adaptive control of penalty weights. The proposed method detects the special type of constraints and specifies a suitable neighborhood search. Computational results for a variety of combinatorial optimization problems show that the proposed method achieves comparable results to the specially tailored algorithms for them.

### 3 - A Software Tool for Interfacing with Linear Programming Solvers

Zachary Steever, University at Buffalo, Buffalo, NY, United States, Chase Murray

Note: We are finalizing a provisional patent for this tool, so we can't disclose details yet. We will update the abstract to be more descriptive well in advance of the conference. We present a new tool to help researchers more efficiently interact with application programming interfaces (APIs) that are often provided by integer programming solvers. This tool streamlines a researcher's typical workflow by automating some steps of the code-writing process. The talk will feature a demonstration of the new software. A roadmap of future enhancements to the tool will be presented, followed by a discussion on how the OR community can influence the incorporation of new functionality into the software.

### 4 - A Novel Lattice-based Douglas Rachford Splitting to Solve Convex Optimization Problems over Integers

Shuvomoy Das Gupta, Thales Canada, Research & Technology, 105 Moatfield Drive, Toronto, ON, M3B 0A4, Canada

Convex optimization problems over integer decision variables have a wide range of applications in transportation, management science, computer science and engineering. In this study, we combine results from lattice theory and monotone operator methods to construct a novel lattice-based Douglas-Rachford splitting algorithm to solve convex optimization problems over integers. The algorithm has several desirable properties, namely: its convex steps are parallelizable, and its nonconvex projection step is reducible into projection onto a lattice in a potentially much smaller dimension. We also establish sufficient conditions for the convergence of the algorithm to an optimal solution.

## 5 - Integer Programming Approaches to Fisheries Observer Assignment

Reed Harder, Dartmouth, 14 Engineering Drive, Hanover, NH, 03755, United States, Vikrant Vaze

Fisheries observers are deployed on commercial fishing vessels to provide independent monitoring of fishing activity. However, effective deployment of observers can present significant challenges in the Western and Central Pacific Ocean: observers board and disembark hundreds of fishing vessels operated by multiple nations at remote ports scattered across the region, and transportation costs between ports can be high. In order to minimize the costs of effective observer deployment, we develop an integer programming approach for assigning observers to scheduled vessel trips, while meeting constraints imposed by the need for impartiality.

## ■ WA53

North Bldg 232A

### Auctions and Competitive Bidding

Sponsored: Auction and Marketing Design

Sponsored Session

Chair: Srinivasa Kartikeya Puranam, LaSalle University, 1900 Olney Ave, Philadelphia, PA, 19141, United States

#### 1 - How Auctioneers Set Ex Ante and Ex Post Reserve Prices in English Auctions

Lijia Tan, Eindhoven University of Technology, Pastoor van Arslaan, 6B, Eindhoven, 5622 CK, Netherlands

We provide the direct experimental comparison of auctioneer behavior in two popular methods of procurement: reserve price English auction and English auction with renegotiation. In our experiment, the auctioneers in these two mechanisms demonstrate systematic biases relative theoretical predictions. We develop a model of subjective conditional probability judgement explains the biases. To demonstrate the robustness of our model, especially relative to standard models and those of anticipated regret we then show in a subsequent experiment that the auctioneer's expected benefit is predicted well out of sample in an environment in which the distribution of seller's cost is right skewed.

#### 2 - Game Theoretic Approaches for Government Acquisition

Scott L. Rosen, Mitre Corporation, 2016 Kenilworth Street, Arlington, VA, 22205, United States, Andreas Tolk, Kelly Horinek, Les Servi, Alex Odeh

This talk investigates the application of game-theoretic models with an optimization engine to provide a quantitative decision support system for the government to illuminate real-time tradeoffs for acquisition decisions. The insight gained is intended to enable the generation of strategies that can quickly move vendors towards the government's preferred negotiation point thus expediting process in acquisition while adding transparency.

#### 3 - An Analysis of Capacity Procurement Game

Lusheng Shao, University of Melbourne, 198 Berkeley Street, Level 10, Melbourne, 3010, Australia

We study a procurement game in which a principal contractor procures production capacities from multiple subcontractors. The subcontractors are heterogeneous in terms of their capacities and production costs. Subcontractor each quote a price that is charged to the principal contractor in exchange for their capacities. We study the optimal bidding strategies of the subcontractors and the optimal procurement strategy of the contractor. We show that in equilibrium the social optimum and collaboration between the subcontractors is achieved.

#### 4 - Bidding and Learning in Repeated Auctions

Srinivasa Kartikeya Puranam, Rutgers University, 227 Penn St, Camden, NJ, 08102, United States, Michael N. Katehakis

We consider the problem of a firm that procures substitutable items in a sequence of auctions by bidding against the "market. The firm and the "market learn from each winning bid. We study bidding strategies for the firm when the objective of the firm is to maximize long run discounted profit.

## ■ WA54

North Bldg 232B

### Behavioral Operations – Beyond Lab Experiments

Sponsored: Behavioral Operations Management

Sponsored Session

Chair: Yinghao Zhang, University of Cincinnati, Cincinnati, OH, 45221, United States

#### 1 - Is Simplicity the Ultimate Sophistication? Wholesale Pricing vs. Non-linear Pricing

Behrooz Pourghannad, University of Minnesota, Minneapolis, MN, 55414, United States, Guangwen Kong, Tony H. Cui

This paper studies a manufacturer's choice of contract when facing a boundedly rational retailer. In a supply chain with a fully rational retailer a wholesale price contract cannot perform better than buy-back and revenue sharing contracts. When the retailer is boundedly rational, we find that a wholesale price contract can dominate both buy-back and revenue sharing contracts. We characterize the condition under which a wholesale price contract is the optimal choice of the manufacturer. Our findings are supported by laboratory experiments in which human suppliers choose a contract to offer to computerized boundedly rational retailers.

#### 2 - Does Loss Aversion Preclude Price Variation?

Ningyuan Chen, Hong Kong University of Science and Technology, Clear Water Bay, Kowloon, Hong Kong

In modern retailing, frequent discounts are seemingly at odds with the idea that price variation antagonizes loss-averse consumers and hence diminishes their demand for products and services. We model a firm selling a product over time to loss-averse consumers who differ in their sensitivity to gains/losses. We show that charging a long-run constant price may be suboptimal and then derive conditions under which the optimal policy is cyclic (e.g., a periodic markdown policy). These findings establish that loss aversion does not preclude price variation and thereby underscore the importance of incorporating consumer heterogeneity into pricing policies.

#### 3 - The Impact of Social Learning on Consumer Subsidies for Green Technology Adoption

Hang Ren, George Mason University, Enterprise Hall, 4400 University Drive, Fairfax, VA, 22030, United States, Tingliang Huang, Georgia Perakis

To incentivize consumer adoption of expensive green-tech products, governments typically order consumers subsidies through rebates and tax credits. Apart from subsidies, consumers' adoption decisions are usually also influenced by the word-of-mouth information about product quality from earlier adopters. In this paper, we study a government's optimal dynamic subsidy decision in the presence of consumers' social learning.

#### 4 - Overconfident Distribution Channels

Meng Li, Rutgers University, 227 Penn Street, Camden, NJ, 08102, United States

We study the effects associated with overconfidence in distribution channels, where overconfidence is defined as a decision maker's cognitive bias in perceiving the expected outcome of an uncertain event as more certain than it likely is. Our results shed some light on the design and adoption of strategies aimed at enhancing decisions and curtailing overconfidence bias of supply chain executives.

#### 5 - Consumer Quality Reference and Offshoring in Product Recalls

Kefeng Xu, University of Texas at San Antonio, 1 UTSA Circle, San Antonio, TX, 78249, United States, Yan Dong, Sining Song, Chen Zhou

Product recalls are often associated with quality failures. We develop an endogenous consumer reference model with stochastic quality levels and consumer valuation of gain-loss utility, to examine the consumer's willingness to buy in the events of recalls. We find that a product recall may revise the consumer belief toward a more negative quality outcome and therefore a lower reference point. The consumer expects a greater gain from buying the product against the lower reference point, leading to higher willingness to buy. Consumer loss aversion and supply chain offshoring are found to significantly affect the consumer willingness to buy and thus firm performance.

## ■ WA55

North Bldg 232C

### The Roles of Supply Chain Knowledge on New Product Introduction

Emerging Topic: New Product Development

Emerging Topic Session

Chair: Junghee Lee, Tulane University, New Orleans, LA, United States

#### 1 - Knowledge-based View of Outsourcing Strategies for New Product: A Game Theory Model

Qiong Chen, University of Science and Technology of China, School of Management, Hefei, 230026, China, Gulru F. Ozkan-Seely, Shouqiang Wang, Aleda Roth

We introduce a signaling game to examine the outsourcing strategies of a buying firm that faces two options in determining a manufacturer to produce its new product: outsource directly or indirectly (through an intermediary). We demonstrate the critical yet interesting role of outsourcing knowledge on the buying firm's outsourcing strategies.



## 2 - Knowledge Outsourcing for Competing Buyers

Jaeseok Lee, Georgia Institute of Technology, 800 West Peachtree  
NW, Atlanta, GA, 30308, United States, Cheryl Gaimon,  
Karthik Ramachandran

We study the knowledge development and outsourcing decisions of competing firms (buyers), who can obtain knowledge from a common supplier. We identify a condition whereby buyers benefit from knowledge outsourcing. We also discuss how the supplier is better off if he serves only one buyer.

## 3 - Market Entry and Location Choice under Market Uncertainty

Wenxin Xu, The Hong Kong Polytechnic University, Hong Kong  
When a new bicycle-sharing company considers pursuing the growth opportunities in emerging markets, e.g., the second or third-tier cities, it often grapples with those questions such as: When should I enter this new market? Where should I locate the docks to serve the customers while avoiding the fierce competitions? This paper provides some managerial insights into the entry timing and location choice under market uncertainty for those companies with a dynamic game-theoretical model.

## 4 - Initial Stage Success Strategies for Mobile Applications

Moonwon Chung, University of South Carolina, Cayce, SC, 29033,  
United States, Luv Sharma, Manoj Malhotra

This study examines the implications of operations decisions in the hypercompetitive context of software development, dissimulation, and sustained service delivery. Specifically, we estimate performance impact of user engagement impacted by the choice of mobile app feature decisions, product launch timing decisions, decentralized value chains, and organizational focus. A panel data of Top 500 ranked mobile game apps in the US was extracted from app market APIs in daily observations over 3 years. We perform econometric analyses to reveal software development and value chain configuration implications for managers.

## ■ WA56

West Bldg 101A

## Optimization in Cancer Treatment

Sponsored: Health Applications

Sponsored Session

Chair: Ali Ajdari, Massachusetts General Hospital & Harvard Medical School, Seattle, WA, 98199, United States

### 1 - A Progressive Hedging Approach for Chemotherapy Appointment Scheduling

Nur Banu Demir, Middle East Technical University, Ankara,  
Turkey, Serhat Gul, Melih Celik

Chemotherapy appointment scheduling in oncology clinics is a challenging combinatorial optimization problem due to the assignment of patients to nurses and chairs. Furthermore, the patient appointment times of a daily patient list must be determined under the uncertainty of the infusion preparation and treatment times. The problem is formulated as a two-stage stochastic mixed integer programming model that minimizes the expected weighted sum of nurse overtime and patient waiting time. A Progressive Hedging Algorithm is applied in order to obtain appointment times for patients. Computational experiments are performed using real data of a major university hospital.

### 2 - Including Edge-penalization Aperture Control Methodologies into VMAT Optimization

Wilmer Henao, University of Michigan, Ann Arbor, MI, United States, Marina A. Epelman, Martha Matuszak, Kelly Younge, Edwin Romeijn

Complex beam aperture shapes consisting of excessive perimeter per unit of area can potentially give rise to dose inaccuracies in VMAT radiation therapy treatments. Standard practice does not explicitly take aperture shape into account at the planning optimization stage. We intend to correct this issue by approximating previously well-established edge penalties, and explicitly incorporating them into the optimization using a column-generation based heuristic. Our algorithm was tested in real cases obtaining a reduction of aperture complexity, an ensuing increase in dose accuracy and a negligible decrease in treatment quality as measured by Dose-Volume Histograms.

### 3 - A Novel Optimal Stopping Approach to Formulate the Radiation Therapy Problem

Ali Ajdari, Research fellow, Massachusetts General Hospital & Harvard Medical School, 125 Nashua st, Boston, MA, 02114,  
United States, Thomas Bortfeld

In the fractionated radiation therapy problem, the treatment is delivered over the course of several sessions. The length of the treatment is usually determined by one-size-fits-all guidelines and is therefore fixed prior to the beginning of radiotherapy course. In some cases however it might be optimal to stop the treatment early to avoid severe normal tissue toxicities and/or over-treating the patient. Using tools in dynamic programming and control theory, we formulate the problem as an optimal stopping model and try to find the optimal time to stop the treatment, based on the observed tumor and normal tissue response.

## ■ WA57

West Bldg 101B

## Resilient Pharmaceutical Supply Chains

Sponsored: Health Applications

Sponsored Session

Chair: Rozhin Doroudi, Northeastern University, Boston, MA, United States

### 1 - Policies to Improve Pharmaceutical Supply Chain Resiliency:

#### A Multi-stage Stochastic Programming Approach

Emily L. Tucker, University of Michigan, Ann Arbor, MI, 48105,  
United States, Mark S. Daskin, Wallace J. Hopp,  
Burgunda V. Sweet

Drug shortages continue to be a major, though little-discussed, public health crisis. They are often caused by disruptions to non-resilient pharmaceutical supply chains. We present a new multi-stage stochastic programming model of the supply chain design problem when components may be disrupted. We discuss the application of a variant of the Stochastic Dual Dynamic Programming algorithm and analyze how policy proposals would affect the risk of shortages under a variety of market conditions.

### 2 - Minimization of Drug Shortages in the Pharmaceutical Supply Chains: A Simulation-Based Analysis of Drug Recall Patterns and Inventory Policies

Rana Azghandi, Northeastern University, Boston, MA, 02215,  
United States, Jacqueline Griffin, Mohammad S. Jalali

The drug shortage crisis in the last decade not only increased health care costs but also put patients' health at risk in the United States. Managing pharmaceutical supply chains is very complex, as inevitable disruptions occur to these supply chains (exogenous factors), which are followed by decisions that members make after such disruptions (internal factors). The current research employs a system dynamics simulation model to examine the effects of different disruption profiles, e.g., the propagation in time and space, and the interactions of decision makers on drug shortages to ascertain how these shortages can be mitigated by changing the inventory policy decisions.

### 3 - Building Up Resilience in a Pharmaceutical Supply Chain through Inventory, Dual Sourcing, and Agility Capacity

Florian Lucker, Cass Business School, 106 Bunhill Row, London,  
EC1Y 8TZ, United Kingdom, Ralf W. Seifert

In this talk we investigate the relationship between the three operational risk mitigation measures inventory, dual sourcing, and agility capacity by modelling a drug manufacturing firm. We quantify the decrease in inventory levels in the presence of dual sourcing and agility capacity. Furthermore, we show how to determine optimal inventory and dual sourcing decisions holistically. Within our modeling framework we introduce an operational metric that quantifies supply chain resilience.

### 4 - Drivers of Drug Shortages: Theoretical and Empirical Investigations

Iva Petrova Rashkova, Washington University-St Louis, Campus  
Box 1156, Business School Faculty, St Louis, MO, 63130,  
United States, Panos Kouvelis

We use the drug shortages FDA data during 2012-2016 to identify the driving forces of drug shortages. We first develop a stylized model illustrating the relationship between drug shortages and changes in the product portfolio of a drug manufacturer. Our key insight is that the potential new drugs, regardless of whether they end up being successful or not, drive drug shortages. We then use data on new brand and generic drugs to show their usefulness in predicting manufacturer's drug shortages. We compare linear regression and random forest predictive models and recommend the latter based on its lower MAPEs both in-sample and out-of-sample.

### 5 - Identifying Critical Components of a Multi Agent Drug Supply Chain

Rozhin Doroudi, Northeastern University, Boston, MA, 02116,  
United States, Ozlem Ergun

The growing epidemic of drug shortages in the US indicates the fragility of drug supply chain in the face of disruptions. Identifying most critical components in the supply chain can assist policy makers in mitigating these shortages. In this study we propose a node criticality measure for underlying network of a drug supply chain in which nodes are agents and arcs are material flow between them. Unlike most node criticality measures in network science literature this measure does not abstract away domain-specific functions of network components. Therefore, it can be used in predicting the effect that disruption of one node can have on the overall supply chain performance.

■ **WA58**

West Bldg 101C

**Joint Session HAS/PSOR/Practice Curated: Emerging Issues in Treatment Planning and Management**

Sponsored: Health Applications

Sponsored Session

Chair: Shengfan Zhang, University of Arkansas, Fayetteville, AR, 72701, United States

**1 - Opioid Overdose and the Role of Comorbidity in US Emergency Departments**

Nisha Nataraj, Centers for Disease Control and Prevention, 4770 Buford Highway, MS - F62, Atlanta, GA, 30319, United States, Kun Zhang, Gery Guy, Christina Mikosz

The United States is in the midst of an opioid overdose epidemic with 42,249 opioid overdose-related deaths in 2016. Certain medical comorbidities may increase the risk for opioid overdose. We use regression and variable clustering models on national-level hospital discharge data to identify comorbidities most associated with opioid overdose in patients presenting to emergency departments. Results show that the overall number of comorbid chronic conditions is increasing in this population and that comorbid psychiatric, neurologic, and fluid/electrolyte disorders are especially associated with overdose.

**2 - A Markov Decision Process Approach to Find the Optimal Time of Operating Lung Volume Reduction Surgery in Patients with Severe Emphysema**

Maryam Alimohammadi, University of Arkansas, Fayetteville, AR, 72701, United States, Shengfan Zhang, Art Chaovalitwongse

Emphysema is a chronic lung disease that can be treated with lung volume reduction surgery (LVRS). Despite the advantages of LVRS in specific patients, it has mortality and morbidity risks and costs more than other treatments which makes it crucial to determine the subgroup of patients that can benefit the most from LVRS and assign them to surgery at the best time. To develop an optimization model that maximizes the quality-adjusted life time of the patients, we used Markov Decision Process (MDP) based on the National Emphysema Treatment Trial (NETT), a comprehensive dataset that collected the data of 1218 patients with severe emphysema who were randomized to undergo surgery or have medical treatment.

**3 - Characterizing the Uncertainty Associated with Treatment Outcomes for Tuberculosis Patients**

Shengfan Zhang, University of Arkansas, 4207 Bell Engineering Center, Department of Industrial Engineering, Fayetteville, AR, 72701, United States

The goal of this research is to use data analytics and stochastic modeling approaches to characterize patient recovery pathway from treatment for tuberculosis (TB). This research will use an existing anonymous data that contain information about follow-up test results for TB patients in Moldova upon initiation of treatment. Specifically, we aim to (1) characterize the pattern of recovery as denoted by the smear and culture test results at follow-ups; and (2) predict patient disposition (i.e., recovered to died) based on the recovery pattern.

**4 - Enhancing Community Resilience to Combat Crisis of Opioid Addiction**

MD Noor E. Alam, Assistant Professor, Northeastern University, 334 Snell Engineering Center, 360 Huntington Avenue, Boston, MA 02115, United States, MD Mahmudul Hasan, Gary Young, Alicia Modestino

This study focuses on detecting the variation of opioids prescribing pattern by leveraging the Massachusetts All Payer Claim Data (MA APCD) set. Based on the meaningful insights obtained from the data mining, we will devise a set of optimal policies to improve the community resilience to combat the opioid addiction epidemic.

■ **WA59**

West Bldg 102A

**Joint Session HAS/Practice Curated: Equity and Efficiency in Treatment of Chronic Illness**

Sponsored: Health Applications

Sponsored Session

Chair: Hadi El-Amine, George Mason University, Fairfax, VA, 22030, United States

**1 - Optimization of Human Leukocyte Antigen Based Donor Recipient Matching in Kidney Transplantation**

Naoru Koizumi, George Mason University, School of Public Policy, 3351 North Fairfax Drive, Arlington, VA, 22201, United States,

Mehdi Nayeypour, Hadi El-Amine

Cold ischemic time and post-operative complications are associated with 30-day mortality of the donor graft. However, long-term patient survival is related primarily to tissue matching, vasculopathy, immunosuppression, and infection. This study examines the preeminent role of tissue matching using an optimization regression algorithm to examine the effect of randomly allocated HLA: A, B, and DR kidney donor on long term patient survival in the largest retrospective study known to date.

**2 - Exploring Models for Reducing Geographical Disparity in Organ Allocation**

Michal Mankowski, King Abdullah University of Science and Technology, Thuwal, Saudi Arabia, Sommer Gentry

Reducing the geographic disparity in access to organs is emerging issues in the transplant community. The OPTN/UNOS has recently appointed the Ad Hoc Geography Committee to define guiding principle and review models for the use of geographic constraints in organ allocation. We investigate a potential impact of some of the approved models.

**3 - Information Theoretic Learning in Markov Decision Processes**

Peeyush Kumar, B14, Industrian and Systems Engineering, MEB, University of Washington Seattle, Seattle, WA, 98195-2650, United States

I will present my research on Markov decision processes where the decision maker is uncertain about the model of the system. To maximize expected reward over the planning horizon, we must balance the exploration versus exploitation tradeoff: learn the transition probabilities sufficiently well, and utilize this information to quickly zero-in on actions with high rewards. I propose Information Directed Policy Sampling, which is an information theoretic framework that explicitly manages this tradeoff. We obtain a worst-case regret bound for IDPS. The theoretical guarantees are supplemented with numerical results on a sequential auction-design problem, and a response-guided dosing problem.

**4 - The Impact of Imperfect Testing on the Performance of Personalized Medical Interventions**

Hadi El-Amine, George Mason University, 4310 Cotswolds Hill Ln, Fairfax, VA, 22030, United States

In this paper, we develop a general framework that analyzes the performance of personalized medical interventions driven by historical patient data. We prove that finding optimal interventions is hard and provide structural properties that provide policy insights.

■ **WA60**

West Bldg 102B

**Joint Session HAS/Practice Curated: New Topics in Healthcare Policy**

Sponsored: Health Applications

Sponsored Session

Chair: Soroush Saghaian, Harvard University, Cambridge, MA, 02138, United States

**1 - The Adoption and Diffusion of Medical Technology: Evidence from Cardiac Procedures**

Ariel Stern, Harvard Business School, Morgan Hall 433, Boston, MA, 02163, United States, Robert Huckman

The adoption of new health care technologies is a learning process, with evidence showing that new products and procedures often involve physician learning and tradeoffs in quality and productivity. We consider the early years of uptake for a new cardiac procedure - transcatheter aortic valve replacement (TAVR) - and its implications for physician procedure mix and patient outcomes. Using data on all aortic valve replacement procedures performed in New York State over five years, we evaluate patterns in the uptake of TAVR across physicians and hospitals as well as patterns of access and receipt among (potential) patients.

**2 - Development of Imminent Mortality Predictor for Advanced Cancer, a Tool to Predict Short-term Mortality in Hospitalized Advanced Cancer Patients**

Junchao Ma, Yale School of Management, New Haven, CT, United States, Edieal J. Pinker, Donald Lee

End-of-life care for advanced cancer patients is aggressive and costly. Although cancer patients rely on oncologists for information about prognosis to make decisions about end-of-life care, physicians tend to over-estimate life expectancy and inconsistently initiate goals of care discussions. We developed and evaluated a novel prognostic tool, which generates life expectancy probabilities in real time using EHR time series to support oncologists in counseling patients about end-of-life care. We will also discuss use of similar decision-support tools to improve quality of care in intensive care units.

### 3 - Do Hospital Closures Improve the Efficiency and Quality of Other Hospitals?

Lina Song, Harvard University, Soroush Saghaian

We study the impact of hospital closures on the surrounding hospitals' efficiency and the mechanisms through which the changes occur. We also investigate the implications of hospital closures on quality. We do these by examining the efficiency, bed utilization, service duration, patient experience, readmissions, and mortality using a nationally representative panel data of Medicare patients. We find that the closure of a hospital in a market results in improvement in efficiency at the remaining hospitals, but this happens at an expense of reducing the service duration. Furthermore, hospital closures are associated with an increase in 30-day mortality of the surrounding hospitals.

### 4 - Can Public Reporting Cure Healthcare? The Role of Quality Transparency in Improving Patient-provider Alignment

Soroush Saghaian, Harvard University, Kennedy School of Government, 79 John F. Kennedy Street, Cambridge, MA, 02138, United States, Wallace J. Hopp

Public reporting of medical treatment outcomes is being widely adopted by policymakers in an effort to increase quality transparency and improve alignment between patient choices and provider capabilities. We examine the soundness of this approach by studying the effects of quality transparency on patient choices, hospital investments, societal outcomes (e.g., patients' social welfare and inequality), and the healthcare market structure (e.g., medical or geographical specialization). Our results offer insights into why previous public reporting efforts have been less than fully successful and suggest ways in which future efforts can be more effective.

## ■ WA61

West Bldg 102C

### Supply Chain Management VI

Contributed Session

Chair: Laharish Guntuka, University of Maryland-College Park, College Park, MD, 20740, United States

#### 1 - A Multi Echelon Supply Chain Model with Multiple Customer Classes

Mohammad Najjartabar Bisheh, Kansas State University, 2061 Rathbone Hall, 1701D Platt St., Manhattan, KS, 66506, United States, Behnam Malmir, Aram Bahrini, Gholamreza Nasiri

In this paper, an integrated model of location-allocation with inventory control decisions is proposed. This model highlights that customers have different value to the central company. The model is single-product and multi-period with stochastic demands. Also, warehouses were considered to have some capacity constraints. The method was solved on a small scale and in the real size as well. For small instances, GMAS software used and for large instances, two meta-heuristic algorithms of classic genetic and hybrid of genetic-simulated annealing were employed. Finally, the quality of solutions and running time of algorithms was analyzed drawing upon the model parameters.

#### 2 - A Contingency Theory Approach to Mitigating Counterfeiting Risk in the Supply Chain

John F. Kros, Vincent K. McMahon Distinguished Professor, East Carolina University, College of Business Dept of M&SCM, 3205 Harold Bate Building, Greenville, NC, 27858-4353, United States, Scott Dellana, Jason Rowe, Mauro Falasca

Counterfeiting is an emerging issue supply chain managers confront. A contingency theory perspective is developed to model the impact of counterfeit prevention efforts on SC performance. A structural equation model examines the relationships among five SC constructs. Our findings suggest that firms with greater SC risk management integration have stronger orientation toward counterfeit risk, greater maturity in counterfeit risk mitigation, more consistent metrics, & better performance outcomes. Interestingly, counterfeit orientation alone was not found to significantly improve metric consistency.

#### 3 - Electric Cars Propagation with Subsidized Supply Chain

Amir Naderpour, PhD Student & EGTA, University of Texas at Arlington, 701 S. West Street, Box 19437, Arlington, TX, 76019, United States

When government's goal is to propagate electric cars in the society, and has the potential to give the same subsidy to the supplier or the retailer of a product, which one should be subsidized to encourage higher quantity of that product? We answered this question in a couple of ways. The first way was game theory. And the theory predicted this supplier retailer relation. To answer our research question, we also used experiment study to see if the results from experiment is consistent with the theory prediction.

### 4 - Collaborative Emission Targets Joining

Dincer Konur, Texas State University, San Marcos, TX, United States

This study analyzes a two-echelon channel under a Stackelberg setting. Particularly, the leader of the channel determines the quantity flow along the channel. Both agents have environmental targets that should be respected. We investigate collaboration mechanisms between the leader and the follower for joining their environmental targets. Two mechanisms are discussed in detail. A comparison between non-collaborative and collaborative emission targets joining decisions is presented.

### 5 - The Impact of Supply Chain Disruptions on Competitors: Propagation of Disruption Impacts Through Supply Chain

Laharish Guntuka, Doctoral Student, University of Maryland-College Park, 4335 Rowalt Drive, #301, College Park, MD, 20740, United States, Adams Steven

We investigate spillover effect of supply chain disruptions on competitor firms who themselves are not involved in the disruption. Measured through abnormal returns and return on assets, the competitors gain when a firm announces a major disruption but the gain is watered down by the number of shared suppliers, vertical relatedness, and supplier exposure, but exacerbated by event exposure.

## ■ WA63

West Bldg 103B

### Joint Session DM/Practice Curated: Data Science for Forecasting and Economic Modeling

Sponsored: Data Mining

Sponsored Session

Chair: Kai Yang, Wayne State University, 4815 Fourth Street, Detroit, MI, 48201, United States

#### 1 - Heteroskedasticity-based Instrumental Variables for Endogeneity Treatment

Bernardo F. Quiroga, Assistant Professor, Pontificia Universidad Católica de Chile, Av. Vicuña Mackenna 4860, Comuna de Macul, Santiago, 29601, Chile

We present a way to achieve econometric identification in instances when outside instruments are not available. By exploiting the structure of the variance-covariance matrix under heteroskedasticity, it is plausible to build orthogonality conditions in presence of endogeneity in otherwise unidentified systems of linear regression equations. Our results build upon the findings presented by different authors in the internal instruments literature (e.g., Arellano and Bond (1991); Lewbel (1996, 2013))

#### 2 - Recent Progresses in Continuous-time Contract Theory

Dylan Possama, Assistant Professor, Columbia University, 500W 120th Street, Mudd 308, New York, NY, 10027, United States

This talk will consists in an overview of recent progresses made in contracting theory, using the so-called dynamic programming approach. The basic situation is that of a principal wanting to hire an Agent to do a task on his behalf, and who has to be properly incentivized. We will show how this general framework allows to treat volatility control problems arising for instance in delegated portfolio management, in electricity pricing, or in central clearing houses. We will also, if time permits, analyze the situation of a Principal hiring a finite number of Agents who can interact with each other, as well as the associated mean-field problem.

#### 3 - How to Project Outpatient Appointments Utilization

Fangzheng Yuan, Doctoral Candidate, UGPTI, 1340 Administration Avenue, Fargo, ND, 58108, United States, Joseph Szmerekovsky, Vera Tilson

In this paper, a probability model known as "shifted-beta-geometric model is implemented as an alternative to commonly used regression models to project the outpatient appointments utilization. This model is easy to use and can be implemented using a simple Excel spreadsheet and the result shows a great accuracy of forecasts and diagnostics for appointment utilization.

#### 4 - A Comparative Study for Patient Workload Prediction

Kai Yang, Wayne State University, 4815 Fourth Street, Detroit, MI, 48201, United States, Mohammad Hessam Olya

This paper suggests a framework for patient workload prediction by using patients' data from VA facilities across the US. To capture the information of patients with similar attributes and make the prediction more accurate, a heuristic cluster-based algorithm for single-task learning is developed in this research. In this research, we have considered patient-dependent and facility-dependent attributes and the relation between tasks into the model while implementing Multi-Task Learning (MTL) approach and training multiple related tasks simultaneously.



## ■ WA64

West Bldg 104A

### Joint Session DM/Practice Curated: Predictive and Prescriptive Analytics

Sponsored: Data Mining

Sponsored Session

Chair: Lianning Zhu, Texas Tech University, Lubbock, TX

#### 1 - L1 Norm Based Major Component Detection Analysis

Qi An, North Carolina State University, Raleigh, NC, 27606,  
United States, Shu-Cherng Fang, Shan Jiang

11 MCDA is a state-of-the-art tool to identify the major components of data with irregularly positioned "spokes". We develop an algorithmic framework of 11 MCDA for multivariate asymmetric radial data clouds. It consists of locating a central point and calculating the major directions and median radii in those direction via a two-level median fitting process. The central point analysis features a pre-selection procedure to screen out candidate points with sufficient data points in the vicinity. Numerical experiments test the proposed analysis methods on high dimensional data set of various configurations and indicate our proposed method demonstrates superior accuracy and robustness.

#### 2 - A Novel Optimization Based Algorithm for Multi-class Data Classification Problem

Fatih Rahim, Ko University, Rumelifeneri Yolu, Sariyer, Istanbul, 34450, Turkey, Metin T rkay

Multi-class data classification is a supervised machine learning problem that involves assigning data to multiple groups. We present a novel MILP-based algorithm that splits each class's data set into subsets such that the subsets of different classes are linearly separable. At each iteration we form a subset of samples out of the set of unassigned samples by a MILP model that maximizes the cardinality of the new subset. The algorithm terminates when all the samples are assigned. We build classifiers based on the convex hulls of the subsets and the polyhedral regions for the testing phase. We conclude that our optimization based algorithm provides competitive results in terms of prediction accuracy.

#### 3 - Heart Rate Estimation using Wrist-type Photoplethysmography Based on Neural Network

Lianning Zhu, Texas Tech University, Lubbock, TX, 79416,  
United States, Dongping Du

Photoplethysmography (PPG) signals from wearable devices are easily corrupted by motion artifact (MA), which poses great difficulties on heart rate (HR) estimation. A moving time window was used to segment PPG signals and ACC signals. Here, a new HR tracking algorithm was developed and denoted as NN-Bayesian. HR prediction was performed by a neural network and HR estimation was performed based on predicted HR and Bayesian decision theory. To validate proposed HR tracking framework, HR estimation was performed using raw PPG signals and cleansed PPG signals which were obtained by spectrum subtraction (SS). The proposed framework shows its accuracy and robustness to track HR.

## ■ WA65

West Bldg 104B

### Joint Session DM/Practice Curated: Data Science and Deep Learning V

Sponsored: Data Mining

Sponsored Session

Chair: Di Wang, University of Illinois at Chicago, Chicago, IL, 60607, United States

#### 1 - Active Batch Learning With Cluster-based Stochastic Query-by-forest (CSQBF)

Ghazal Shams, Arizona State University, Tempe, AZ, 85282, United States, Seho Kee, Enrique Del Castillo, Eugene Tuv, George Runger

Modern systems use automated sensing that can generate a large number of unlabeled instances at low cost, but obtaining labels may require human effort that is time-consuming and expensive. In this work, we propose the Cluster-based Stochastic Query-By-Forest (CSQBF) algorithm which introduces an enhanced stochastic querying strategy by combining the supervised knowledge of a trained classifier on the labeled data with unlabeled data cluster information iteratively in a pool-based active learning scenario.

#### 2 - Matched Forest for High-dimensional Matched Case-control Studies

Nooshin Shomal Zadeh, PhD Student, Arizona State University, 699 S. Mill Ave, Tempe, AZ, 85281, United States, Sangdi Lin, George Runger

Matched case-control study designs are commonly used in clinical studies to identify exposure variables associated with a medical condition. Matching is a preprocessing approach which is used in case-control studies to improve the efficiency by enforcing the confounding variables to have same distributions for cases and controls. Existing methods for analyzing matched case-control data sets have limitations in high-dimensional setting (for matching or exposure variables) and with interaction effects. This research proposes a new learning method which is not only flexible for a number of matching and exposure variables, but can also detect interaction effects.

#### 3 - A Multi-model Approach for Sports Betting Recommendation

Ismail T. Yumru, Data Scientist, Algopoly, Istanbul, 34342, Turkey, Mustafa Gokce Baydogan, Berk Orbay

Statistical learning methods are increasingly used in the domain of sports result prediction, where estimating the probabilities of possible outcomes (odds) of a game better than a bookmaker does is key to making profit. In this study, several learning techniques such as multinomial penalized regression, random forest and gradient boosting are carried out first to estimate the odds, then to select the subsets of games that are most likely to be profitable.

#### 4 - Learning Based Mission Planning for Solar Powered Multi Robot System

Di Wang, University of Illinois at Chicago, Chicago, IL, 60607, United States, Mengqi Hu, Yang Gao

To improve the long duration operation for multi-robot system, the solar-powered robot has attracted greater attention. In this research, we propose a Markov decision model for solar-powered multi-robot mission planning to co-optimize the task allocation and energy schedule. A deep reinforcement learning algorithm is developed to solve the Markov model considering various objectives, such as minimizing traveling distance, traveling time and net energy consumption. Without retraining for new problem instance, the proposed algorithm can generate near optimal mission planning and energy scheduling decisions.

## ■ WA66

West Bldg 105A

### Practice – Data Mining & Control in Manufacturing

Contributed Session

Chair: Arun Chockalingam, Eindhoven University of Technology, Hoog Gagel 62, Eindhoven, 5611BG, Netherlands

#### 1 - Machine Learning-based Quality Prediction for Smart Manufacturing in SMT Process

Dongil Kim, Assistant Professor, Chungnam National University, 99 Daehak-ro, Yuseong-gu, Daejeon, Korea, Republic of, Hyein Kim, Jeongin Koo, Sungsoo Choi, Sang-Hyun Lee, Jeong Tae Kang

Surface Mount Technology (SMT) process is one of the most important processes in electronics industry. Through the SMT process, electronic chips are mounted on a Printed Circuit Board (PCB), and released as final products. Hence, the final quality of product is determined with the SMT process. In this paper, we propose a machine learning-based quality prediction method for SMT process. The input data were collected from the equipment in the process, such as reflow/soldering process. In addition, external variables, such as weather information, were also employed. We evaluate the performance of the proposed method through a real-world SMT process dataset, and the important factors are analyzed.

#### 2 - A Study on Data Preprocessing Method for Relationship and Characterization of Cutting Process Monitoring Signals

Hyein Kim, Korea Institute of Industrial Technology, Cheonan, Korea, Republic of, Dongil Kim, Jeongin Koo

The importance of monitoring, anomalous prediction and autonomous control is increasing to prevent and respond to unusual situation for maintaining the accuracy and operation rate of CNC. To propose optimal machining conditions, we measure the status of real time process through the CNC communication. Based on this, we have attached various sensors to the CNC to collect data on all the situations that occur during machining to understand the relationship and characteristics between the monitoring signals. To clarify relationships of collected data, we set up a machining section based on the position of the axis and applied a variety of analytical methods to perform the data preprocessing process.

#### 3 - Operationalizing the Offshoring Decision

Arun Chockalingam, Assistant Professor, Eindhoven University of Technology, Den Dolech 2, Eindhoven, 5612AZ, Netherlands, Haolin Feng

We consider a manufacturer who has both onshore and offshore production facilities. The manufacturer can dynamically allocate production between both facilities. Adjusting the production allocation incurs both fixed and proportional costs. We formulate this allocation problem as a stochastic-impulse control problem and derive the optimal allocation policy.

#### 4 - Time Allocation Strategy for Evolutionary Process in Biomanufacturing

Mahdi Fatihi, University of Florida, 401 Weil Hall P.O. Box 116595, Gainesville, FL, United States, Marzieh Khakifirooz, Chen-Fu Chien

The most challenging issue in Biomanufacturing is the process constrained on minimal and maximal times for specific process. When molecules limitation versus time limitation assessing the relative incidence of the exhaustion between supply before death versus death before exhaustion of supply and highly depends on the quality of molecules. On the other hand, the stochasticity in market demand precludes a precise evolutionary matching of time allocation and productivity opportunity. This problem is modeled as a multiobjective Pareto optimality problem to minimize the cost per material and cost per time subject to constraints of accelerated evolutionary distribution of molecules.

#### ■ WA67

West Bldg 105B

#### Joint Session ISS/Practice Curated: Empirical Studies on Platforms

Sponsored: Information Systems

Sponsored Session

Chair: Fujie Jin, Kelley School of Business, Indiana University, Bloomington, IN, 47401, United States

#### 1 - A Deep Learning Approach to Better Understanding of Hospital Quality

Weiguang Wang, University of Maryland, 3330 Van Munching Hall, R.H. Smith Business School, College Park, MD, 20740, United States, Guodong (Gordon) Gao

Hospitals are plagued with quality issues. It is well recognized that factors of providers and patients both contribute to quality issues, but how to separate their effects remains a challenge. We design a deep-learning based method that shows great promise in solving this problem. Firstly, word embedding techniques are adopted to vectorize all elements captured by EHRs. Then a one-to-one model is built using machine learning to link vector representations to hospital quality. Finally, a modification process to remove the effect of certain factors is performed to examine the impact of them on hospital quality. The proposed model is applied to real-world examples using the Florida provider data.

#### 2 - Seeking a Reward or Helping the Entrepreneur-backers Response to a Low-price Probabilistic Choice in Reward-based Crowdfunding

Alvin Zuyin Zheng, Temple University, 1801 N. Broad St, Pennsylvania, Philadelphia, PA, 19122, United States, Jing Gong, Paul Pavlou

Crowdfunding aims to collect small investments from a large number of backers. Since crowdfunding projects typically attract a small number of backers, this study examines the role of the lottery in crowdfunding outcomes. Using a four-year dataset from a reward-based crowdfunding platform in China, we show that although the lottery does indeed help attract a higher number of backers for a project, it reduces the total money raised and the probability of reaching the funding goal. Mechanism analyses show the lottery incentivizes people who would otherwise not fund the project to become opportunistic backers, the lottery also cannibalizes prospective rewarders and donors.

#### 3 - How Does Online Lending Influence Bankruptcy Filings? Evidence from a Natural Experiment

Hongchang Wang, Georgia Institute of Technology, Atlanta, GA, United States, Eric Overby

By providing relatively quick and easy access to credit, online lending platforms may help people overcome financial setbacks and/or refinance high-interest debt, thereby decreasing bankruptcy filings. On the other hand, these platforms may cause people to overextend themselves financially, leading to a "debt trap and increasing bankruptcy filings. To investigate the impact of online lending on bankruptcy filings, we leverage a natural experiment: Lending Club's entry into different states at different times. Using coarsened exact matching and a difference-in-differences approach, we find that Lending Club's entry increases bankruptcy filings by approximately 8%.

#### 4 - Beauty and Counter-signaling in Two-sided Matching Markets: Evidence from a Randomized Field Experiment

Lanfei Shi, University of Maryland, 3330 Van Munching Hall, College Park, MD, 20742, United States

While online platforms place trust at the center, markets with few alternative trust-inducing signals face an even bigger challenge. In such cases, we find that phone verification, when making it optional and visible to others, plays a more significant and strategic role that works as an effective signaling device. We also identify interesting differential ex-ante opt-in decisions and ex-post impact of verification across two sides of the platform. We further discuss the underlying mechanism by applying state-of-the-art deep learning techniques to mine attractiveness using images. Moreover, upon verification users become more proactive, which also contributes to the increase in matching.

#### ■ WA68

West Bldg 105C

#### Big Data Modeling and Monitoring

Sponsored: Quality, Statistics and Reliability

Sponsored Session

Chair: Xiaochen Xian, UW-Madison, Madison, WI, 53705, United States

Co-Chair: Kaibo Liu, UW-Madison, Madison, WI, 53706, United States

#### 1 - Unsupervised Point Anomaly Detection Using Neighborhood Structure Assisted Non-negative Matrix Factorization

Imtiaz Ahmed, Texas A. & M. University, College Station, TX, 77840, United States, Yu Ding, Xia Ben Hu

Anomaly detection is unsupervised in nature and we can only rely on the neighborhood structure of a point for its evaluation. In this paper, we develop an anomaly detection procedure under the non-negative matrix factorization (NMF) framework. We incorporate the structural similarity information in the original NMF setting and propose a new approach called Neighborhood Structure Assisted NMF (NS-NMF). We argue that it will increase the anomaly detection capability of the regular NMF and provide numerical evidence in support of our claim. We also compare our method with other close developments in the same family and provide a detailed comparative evaluation on 20 benchmark data sets.

#### 2 - Concept Drift Monitoring of Supervised Learning Models via Score Functions

Kungang Zhang, Daniel Apley, Anh Bui

Predictive models are trained on historical data and applied to new data. However, the true predictive relationship between the response and the predictors may change over time (aka, concept drift), rendering the fitted model obsolete. We propose to monitor such drift via multivariate control charting to detect changes in the mean of the score function, which is zero-mean if there is no drift. The score function is automatically produced in stochastic gradient optimization as the derivative of the log-likelihood. The method provides guidance on when the model should be updated for optimal prediction following a drift, as well as diagnostic information on the nature of the drift.

#### 3 - A Density-based Index for Clustering Validation

Behnam Tavakkol, Stockton University, Galloway, NJ, United States, Myong Kee Jeong, Susan Albin

Clustering validity indices are the main tools of evaluating the quality of clusters. In this study, we develop a density-based clustering validity index. As opposed to most clustering validity indices that capture the characteristics of clusters by representative statistics, the proposed validity index performances well on clusters with arbitrary shapes.

#### 4 - Spatiotemporal Modeling and Real-time Prediction of Origin-destination Traffic Demand

Xiaochen Xian, UW-Madison, Madison, WI, 53705, United States, Kaibo Liu

New technology has enabled new opportunities in a data-rich environment for the traffic research. To provide an accurate input for traffic planning, scheduling, and optimization problems, we propose a spatiotemporal modeling technique for the OD demand of the traffic network. In particular, the OD demand counts are handled by a Poisson log-normal model; and the mean and covariance matrix of the model are parametrized by the features of the traffic network. Then the method estimates the parameters using the EM algorithm and online predicts the traffic demand collectively considering both the spatial and temporal correlations.

#### ■ WA69

West Bldg 106A

#### Statistical Aspects of Computer Experiments and Stochastic Simulation

Sponsored: Quality, Statistics and Reliability

Sponsored Session

Chair: Qiong Zhang, Richmond, VA, 23284, United States

#### 1 - Asymmetric Kriging Emulator for Risk Measurement of Stochastic Simulation

Qiong Zhang, 1015 Floyd Ave, Richmond, VA, 23284, United States

Expectile is known to be the only risk measure that is both coherent and elicitable. Due to its good property, expectile recently attracts more and more attention in risk management. In stochastic simulation, it is often required to precisely estimate the system risk performance for a large number of input points. Therefore, it is particularly important to develop a statistical emulator for the expectiles of stochastic simulation. In this talk, I will introduce a new approach, called Asymmetric Kriging, to emulate the expectile risk measure of stochastic simulation. Our approach can be reduced to the state-of-art approach, stochastic Kriging, in emulating the mean performance measure.

## 2 - A Metamodel-assisted Framework for Two-stage Optimization via Simulation

Wei Xie, Yuan Yi

For the discrete two-stage optimization with the unknown response obtained from simulation, we introduce a metamodel-assisted framework that can efficiently employ the simulation resource to iteratively solve for the optimal first- and second-stage decisions. At each visited first-stage decision, we develop a local metamodel to solve a set of deterministic recourse problems simultaneously. Then, we construct a global metamodel accounting for the finite sampling error from SAA and the second-stage optimality gap. Assisted by this global-local metamodel, we propose a simulation optimization approach that can efficiently guide the search for the optimal first- and second-stage decisions.

## 3 - Design & Analysis of a Computer Experiment for an Aerospace Conformance Study

David Edwards, Virginia Commonwealth University, 1015 Floyd Avenue, P.O. Box 843083, Richmond, VA, 23284, United States

Within NASA's Air Traffic Management Technology Demonstration, Interval Management (IM) is a flight deck tool that enables pilots to achieve or maintain a precise in-trail spacing behind a target aircraft. Previous research has shown that violations of aircraft spacing requirements can occur between an IM aircraft and its surrounding non-IM aircraft when it is following a target on a separate route. This talk focuses on the experimental design and analysis of a computer experiment which models the airspace configuration of interest in order to determine airspace/aircraft conditions leading to spacing violations during IM operation.

## 4 - Varying Coefficient Gaussian Processes for Computer Models with Quantitative and Qualitative Inputs

Xinwei Deng, Department of Statistics, Virginia Tech, 406 Hutcheson Hall, Blacksburg, VA, 24061, United States

Computer experiments with both qualitative and quantitative factors attracts wide attentions. Analysis of such experiments is not yet completely resolved. In this work, we propose a varying coefficient Gaussian process to model computer experiments with qualitative and quantitative factors. The proposed method considers the coefficient associated with the qualitative factor to be a varying coefficient of the quantitative factors. It embraces a flexible structure of incorporating qualitative factors in modeling the complex systems of computer experiments. The merits of the proposed method are illustrated by both numerical examples and real-data applications.

## 5 - Modeling and Forecast of Noisy Nonlinear Dynamics

Youngdeok Hwang, Sungkyunkwan University, Department of Statistics, 25-2 Sungkyunkwanro, Seoul, 03063, Korea, Republic of, Kyongmin Yeo, EunKyung Lee

Data-driven modeling of a complex physical process is of current interest due to its direct relevance to manufacturing. Although domain knowledge on the underlying physical process has been playing a key role in understanding manufacturing processes, it is often impractical or impossible to build physics models from the first principles. Here, we propose a Recurrent Neural Network (RNN) based model for the nonlinear system identification and forecast of a stochastic process with an underlying physical process.

## ■ WA70

West Bldg 106B

## Fault Diagnosis and Tolerant Control for System Reliability Improvement

Sponsored: Quality, Statistics and Reliability

Sponsored Session

Chair: Yimin Zhou, Shenzhen Institutes of Advanced Technology, Chinese Academy, 1068 Xueyuan Avenue, Shenzhen University Town, Shenzhen, Guangdong, 518055, China

## 1 - The Prospect of Smart Cars: The Combination of Robotized Technology and Intelligent Vehicles

Yimin Zhou, Chinese Academy, 1068 Xueyuan Avenue, Shenzhen University Town, Shenzhen, Guangdong, 518055, China, Qin Lv, Qingtian Wu

In this paper, the development of the robotized technology has been described. Since the first robot has been designed, robots have been gone through three generations from the individual robots to intelligent robots from 60's. Potential development directions of the robotic technology is discussed. Besides, the problems encountered during the research are also analyzed, including stability control, reliability control and fault tolerant control. Furthermore, the robotized technologies are applied in the intelligent electric vehicles to improve the driving safety in human-road-vehicle environment. The driving strategy, vehicle monitoring and human-machine interaction are reviewed in details.

## 2 - Action Detection and Abnormal Event Detection for Surveillance Monitoring Under Mobile Vehicle or Moving Camera

Qingtian Wu, Shenzhen Institutes of Advanced Technology, Beijing, China

In outdoor environments, many cameras have been fixed in main roads, entrances to monitor abnormal event for better security. However, in some areas such as shade or turning corner, coverage monitoring cannot be achieved due to the limited monitoring distance and angle constraints of fixed camera. In order to monitor the blind spots under the fixed camera and track the incident centroid, a rapid detection of abnormal behavior system based on the mobile robot is proposed to detect abnormal events. The system can be embedded in a patrol robot which is used in the community environment to shoot the real-time scene information by vehicle-mounted camera, then to analyze of the monitoring area through intelligent visual detection algorithm. If abnormal event occurs, alarm will be triggered to alarm the guard.

## 3 - Actuator Fault Tolerant Control Algorithm with Application to a Quadcopters

Yimin Zhou, Shenzhen Institutes of Advanced Technology, 1068 Xueyuan Avenue, Shenzhen University Town, Shenzhen, Guangdong, 518055, China, Kranthi Kumar Deveerasetty

This paper investigates a rotor failure on the quadcopter. The goal is to detect the fault and to design a controller to make the quadcopter to perform the hover and trajectory task. The task of the controller is to make the quadcopter to perform a stable spin around its vertical axis when a rotor fault occurs. The UAV will work as a tri-copter to perform the desired tasks. The proposed controller is developed based on the feedback linearization approach and compared with PID controllers. We consider only smooth trajectory by avoiding the sharp turn's to maintain the minimal acceleration. Simulation results show the efficacy of the proposed controller towards the UAV reliability and safety improvement.

## ■ WA71

West Bldg 106C

## Joint Session ICS/Practice Curated: Dynamic Stochastic Optimization in Urban Transportation

Sponsored: Computing

Sponsored Session

Chair: Qie He, University of Minnesota, Minneapolis, MN, 55455, United States

## 1 - Travel Time Estimation in the Age of Big Data

Sebastian Martin, Massachusetts Institute of Technology, Cambridge, MA, 02139, United States, Patrick Jaillet, Dimitris Bertsimas, Arthur J. Delarue

While travel time estimation has become increasingly mainstream and accurate, it is hard to build application-specific estimations that are reliable and compare with the state of the art without access to clean travel time datasets and detailed routing network information. We develop a method that tractably exploits any amount of origin-destination data and only needs a simplified routing network to build accurate estimations. Using data from the Manhattan taxis, we show that our algorithm can provide insights about urban traffic patterns on different scales and accurate travel time estimations throughout the network. Boston also used it to better route school buses and save millions of dollars.

## 2 - Absenteeism Prediction and Extra-board Driver Scheduling for Bus Transit Operations

Xiaochen Zhang, University of Minnesota, Minneapolis, MN, 55454, United States, Qie He

We develop a data-driven analytics tool to assist daily scheduling of extra-board drivers in bus transit operations. Extra-board and overtime drivers are used to cover open jobs due to the absences of regular drivers. We build a hierarchical regression model to forecast the daily absences. With the prediction, we develop a two-stage stochastic programming model to determine the daily optimal assignment of extra-board drivers and use of overtime, which also makes recommendations on the daily extra-board size. Our model's recommended assignment based on historical data reduces the expected total operating cost significantly while the probability of losing service remains low.

## 3 - An Integrated Dynamic Ridesharing Dispatch and Idle Vehicle Repositioning Strategy on a Bimodal Transport Network

Saeid Rasulkhani, Tai-Yu Ma, Joseph Y.J. Chow, Sylvain Klein

In bimodal ridesharing, a private on-demand mobility service operator offers to drop off a passenger at a transit station, where the passenger uses the transit network to get to another transit station, and the service operator guarantees picking up the passenger (not necessarily with the same vehicle) to drop them off at the final destination. We consider dynamic bimodal ridesharing problems where real-time information is available to anticipate future demand. A new non-myopic vehicle dispatching and routing policy based on queueing-theoretical approach is proposed and integrated with a non-myopic idle vehicle repositioning strategy from the literature to solve the problem.



#### 4 - Dynamic Pricing and Resource Allocation in Driverless Ridesharing Systems

Chao Lei, University of Illinois at Urbana-Champaign, 205 N. Mathews Ave., Urbana, IL, 61801, United States, Zhoutong Jiang, Yanfeng Ouyang

We propose a multi-period game-theoretic model for the dynamic ridesharing pricing and idling vehicle reallocation problem in the context of driverless vehicles being applied to providing on-demand ridesharing services. The goal is to achieve the best utilization of ridesharing resources in both spatial and temporal dimensions through the game-theoretic optimization. A mathematical program with equilibrium constraints (MPEC) formulation is developed to capture the independent decision-making process of the mobility service provider and travelers. A non-myopic approximate dynamic programming (ADP) based algorithm is implemented as the solution approach.

#### ■ WA72

West Bldg 211A

#### Practice- Operations Management II

Contributed Session

Chair: Horst Tempelmeier, Universitaet zu Koeln, Albertus Magnus Platz, Seminar fuer SCM und Produktion, Koeln, D. 50923, Germany

##### 1 - Research on Decision Optimization of Low Carbon Remanufacturing Production under Financing Strategy

Xiaodong Xia, Southeast University, Nanjing, China, Weida Chen

**Abstract:** This paper devotes to integrating the financial strategies which consists of bank loan, stock financing, debt financing, and financing lease into low carbon remanufacturing production decisions. The remanufacturer can get economical aid by financing to optimize its promotion, which is a convex optimization problem in a nonlinear programming model that can be solved by intelligence algorithms. Finally, there is a hot discussion about optimal production decisions on different financing modes to get better production strategy. **Key words:** Remanufacturing production decision; financial strategies; Nonlinear programming model; Intelligence algorithms

##### 2 - How the Technology Constraint and Cannibalization Affect Firm's Product Introduction Strategy

Yi Liu, Pennsylvania State University, University Park, PA, 16802, United States, Nicholas C. Petruzzii

We consider the optimal product design question for a firm in a two-segment market characterized by heterogeneous customer valuations of product quality. The firm's product quality is currently limited by a technology constraint that can be removed if product introduction is delayed by one time period. The question is, what, if any product should be introduced now and what, if any, should be introduced later.

##### 3 - Forecast Horizons under Demand Substitution and Backlogging and Production Changeovers with Batch Production

Fuying Jing, Dr., University of Electronic Science and Technology of China, Chengdu, China, Yinping Mu

This paper studies forecast horizons for a two-product dynamic lot size problem under (i) one-way substitution, that is one product can be used to satisfy the demand of the other product but not vice versa; and (ii) the production rate to be any value in the set  $\{0, Q, 2Q, \dots, nQ\}$ , where  $n$  is nonnegative integer; and (iii) backlogging is permitted. It is assumed that the switching cost is occurred when production switches from one product to the other. Based on some properties of the optimal solution, we develop a DP algorithm to solve the problem. By establishing the monotonicity of the production point of two products, we give a sufficient condition to obtain the forecast horizon.

##### 4 - Supply Allocation of Multiple Services on the Ride-hailing Platform

Shuanglong Wang, PhD Student, University of Illinois-Urbana Champaign, Champaign, IL, 61820, United States, Xin Chen

It's a common practice for a ride-hailing platform to manage multiple substitutable services. The platform has to manage the qualities of services by allocating the incoming drivers among them. We use the expected waiting time to capture the qualities of different services and assume that the drivers arrive passively during demand shock. We use the MNL model to describe the choice behavior of waiting-time-sensitive riders and look at the long-term equilibrium between rider's choices and the platform's allocation policy. The optimal strategies of supply allocation are investigated accordingly.

##### 5 - Dynamic Capacitated Lot Sizing with Random Demand and Random Yield

Horst Tempelmeier, Professor, University of Cologne, Albertus Magnus Platz, Department of SCM and Production, Cologne, D. 50923, Germany

We consider a dynamic multi-item capacitated lot sizing problem under stochastic demand and random yield. We develop a planning model which is based on the static uncertainty strategy by Bookbinder and Tan (1988) whereby a cycle fill rate constraint is implemented to control the amount of backorders. We propose

several heuristic solution approaches which extend our earlier work on stochastic lotsizing to the considered case of imperfect yield. The performance of the new solution approaches is analyzed with a numerical experiment.

#### ■ WA73

West Bldg 211B

#### JFIG Panel Discussion: How to Build Your Network

Sponsored: Junior Faculty JFIG

Sponsored Session

Chair: Gokce Palak, Shenandoah University, Winchester, VA, 22601, United States

Co-Chair: Canan Gunes Corlu, Boston University, Boston, MA, 02215, United States

##### 1 - JFIG Panel Discussion: How to Build Your Network

Gokce Palak, Shenandoah University, 1460 University Dr., Winchester, VA, 22601, United States

This session features presentations by panelists who will share their experiences and insights about building your network.

##### Panelists

Sandra D. Eksioglu, Clemson University, 277C Freeman Hall, Department of Industrial Engineering, Clemson, SC, 29634, United States

Laurens G. Debo, Dartmouth College, 100 Tuck Hall, Hanover, NH, 03755, United States

Russell R. Barton, Pennsylvania State University, 210 Business Building, University Park, PA, 16802, United States

Dessislava Pachamanova, Babson College, Math/Science Dept, 319 Babson Hall, Babson Park, MA, 02457, United States

#### ■ WA74

West Bldg 212A

#### Joint Session MCDM/Practice Curated: Understanding Multiple Criteria in Healthcare Applications

Sponsored: Multiple Criteria Decision Making

Sponsored Session

Chair: Gilberto Montibeller, Loughborough University, School of Business & Economics, Loughborough, LE11 3TU, United Kingdom

##### 1 - Healthcare Resource Allocation in Accountable Care Organizations Based on Data Envelopment Analysis and Multi-objective Integer Programming Approach

Hasan Symum, Graduate Assistant, University of South Florida, Tampa, FL, 33612, United States

Accountable Care Organizations (ACOs) represents a major healthcare reform that aimed to better control cost while improving care quality. However, only (30% -35%) of the ACOs were able to generate savings from Medicare due to lack of coordination and consistency in care. We propose bi-level multi-objective DEA based decision support system that allocates patients and healthcare resources to the ACOs decision-making unit (DMU) by assigning protocols to minimize spending and variability in care under Medicare-ACO contract framework. It provides a comparison between centralized decision making with the existing system and bi-level model improves overall DMU's efficiency level significantly.

##### 2 - A Strategic Modeling for the Allocation of Ambulance Request to Emergency Departments in the United States System

Jorge Acuna, PhD Student, University of South Florida, 4202 E. Fowler Avenue, Tampa, FL, 33620, United States

Being able to assign efficiently the services request to emergency departments (ED's) is of paramount importance both from financial and life-threatening scenarios. Three strategies based on mixed integer programming for multi-objective optimization, min-max, and game theory approaches, are implemented to improve the ambulance allocation in the U.S. system. A hypothetical scenario of a county is used to compare the efficiency and fairness of each strategy. Policies and disparities implications are analyzed and discussed.

### 3 - A Multi-attribute Optimization Approach for Post-acute Provider Selection

Ashkan Hassani, Texas A&M University, 4050 ETB, College Station, TX, 77840, United States, Hossein Badri, Maryam Khatami, Kai Yang, Mark Alan Lawley

In this study a decision making approach is developed for Post-Acute Care Provider (PACP) selection problem. This approach includes two stages. In the first stage, some quality metrics are used in a TOPSIS method to calculate the closeness coefficients of each candidate PACP to short-stay patient's and long-stay patients. In the second stage, these coefficients are used in a mathematical programming model, along with some other cost and service level metrics to select the best PACP's for both short-stay and long-stay patients. The proposed approach is implemented for PACP selection problem in the city of Houston, TX, and the results are presented and analyzed.

### 4 - Using Pareto-efficient Analysis to Incorporate the Six Aims for Quality in the Analysis of Trauma Care Services

Lucy Aragon, Wichita State University, 1845 Fairmount Street, Wichita, KS, 67260, United States, Laila Cure

The Institute of Medicine proposed six aims to guide healthcare quality improvement efforts. However, most healthcare improvement programs still evaluate quality along one aim at a time, effectiveness. This research proposes a Pareto-efficient analysis to incorporate all six aims in the evaluation of healthcare quality. A trauma care setting is used to investigate data requirements, develop the methodology and evaluate its implications.

## ■ WA75

West Bldg 212B

### Planning for Assessments and Analyses

Sponsored: Military and Security

Sponsored Session

Chair: Andrew Keith, Air Force Institute of Technology, Dayton, OH, 45424, United States

#### 1 - Operations Assessment Planning Using Robust Partially Observable Markov Decision Processes

Andrew Keith, Air Force Institute of Technology, Dayton, OH, United States, Darryl K. Ahner

Military operations assessment planning involves sequential decision making under model uncertainty and partial state observability. Robust partially observable Markov decision processes extend traditional Markov decision processes to address this complex setting. We present a novel robust partially observable Markov decision process formulation and solution technique. Then, we compare the performance of the new solution technique to existing methods using classic problems from the literature. We demonstrate the application of the new methods to a notional operations assessment planning scenario.

#### 2 - Designing the Bayesian Enterprise Analysis Model (BEAM)

Mark Gallagher, Randy Saunders

Bayesian Enterprise Analysis Model (BEAM) is an enterprise model that models the probability distribution of quantities of assets in theater. BEAM is intended to search strategy tradeoffs where assets are assigned to different missions. BEAM also models Red assets to account for an adversary adapting their strategy. BEAM calculates the distribution of modeled results with Bayesian methods applied to the objects and missions in each cycle's plan. We describe the theoretic results, analysis challenges, and questions being explored in the prototype.

#### 3 - Weighted Laplacian-regularized Optimal Experimental Design for Expensive Tests with Outliers: An Application in Linear-elastic Fracture Mechanics

Stanford Martinez, Graduate Research Assistant, University of Texas at San Antonio, 1 Utsa Circle, San Antonio, TX, 78249, United States, Adel Alaeddini

In the design of experiments, traditional space-filling methods do not preserve the geometry of the design vectors involved in the experiment. This can be mitigated using Laplacian Regularization (LR), and rare events present in the experiment may be discovered via outlier detection. Such events may be caused by material defects or other occurrences during an experiment, as occasionally encountered in fracture mechanics. The effects of this combination of LR and outlier detection are studied alongside traditional methods in terms of design efficiency and practicality-of-use.

#### 4 - Optimization of Bandwidth in Constrained Networks of Cross-domain Unmanned Systems

McKenzie Worden, University at Buffalo-CUBRC, 4455 Genesee Street, Buffalo, NY, 14225, United States

Using a multi-phase, iterative heuristic approach, we aim to define information collection and exchange between unmanned resources and control stations in a bandwidth constrained network. Initial decisions will be made determining the areas from which resources' sensors will collect information. Using these decisions, and considering bandwidth and communication range restrictions, the

heuristic will then determine when, and how much of, the collected information will be sent back to the control station, either directly or via other resources as relays.

## ■ WA76

West Bldg 212C

### Academic Job Search Panel

Sponsored: Minority Issues

Sponsored Session

Chair: Eduardo Perez, Texas State University, San Marcos, TX, 78666, United States

#### 1 - Job Search Strategies for Academic Positions

Eduardo Perez, Texas State University, Roy F. Mitte Complex, 749 N. Comanche St., San Marcos, TX, 78666, United States

Five panelists will be sharing their experience as chair of faculty search committees at their respective institutions. The panel is integrated by: Dr. Mingzhou Jin from The University of Tennessee, Dr. Emmett J. Lodree from The University of Alabama, Dr. Clara Novoa from Texas State University, Dr. Lewis Ntamo from Texas A&M University, and Dr. Chiwoo Park from Florida State University.

#### Panelists

Mingzhou Jin, University of Tennessee-Knoxville, 525D John D. Tickle Engineering Building, Industrial and Systems Engineering, Knoxville, TN, 37996, United States

Emmett J. Lodree, University of Alabama, Info Systems, Statistics, and Mgt Science, Box 870226, Tuscaloosa, AL, 35487-0226, United States

Clara Novoa, Texas State University, 120 Azolar Drive, San Marcos, TX, 78666, United States

Lewis Ntamo, Texas A&M University, 3131 TAMU, College Station, TX, 77843, United States

Chiwoo Park, FAMU-FSU College of Engineering, 2525 Pottsdamer St, Tallahassee, FL, 32310-6046, United States

## ■ WA77

West Bldg 213A

### Matchings and Assignments with Societal Impact

Sponsored: Public Sector OR

Sponsored Session

Chair: Andrew C. Trapp, Worcester Polytechnic Institute, Worcester, MA, 01609, United States

#### 1 - Machine Learning and Optimization for Service Classification and Assignment of Information Technology Services

Pitchaya Wiratchotisatian, Worcester Polytechnic Institute, Worcester, MA, 01609, United States, Andrew C. Trapp, Christopher J. Chagnon, Soussan Djamassbi

IT help desks assist users with a variety of services. However, ad-hoc, inconsistent handling of help desk tickets can lead to issues with customer experience and increasing cost. We propose a decision support system that embeds machine learning techniques to classify incoming tickets according to service categories. Based on the service category, along with available technician capacity and skill sets, it uses combinatorial optimization techniques to assign tickets to technicians. Our system ensures that the right tickets get to the right technicians, resulting in improved use of resources.

#### 2 - Optimization-based Mechanism for Matching Students to International Projects

Hoda Atef Yekta, University of Connecticut, Storrs, CT, 06066, United States, Andrew C. Trapp, Pitchaya Wiratchotisatian

Global projects are a cornerstone of the project-based curriculum at Worcester Polytechnic Institute (WPI), which has been recognized with the Bernard M. Gordon Prize from the US National Academy of Engineering. Recent increases in applications have caused the manual process of placing students (nearly 1,000) into international project centers (nearly 50) to become increasingly complex. We propose an optimization-based approach that matches students to project centers by considering student preferences, as well as center capacities and priorities over student skills. We compare the results of our model with other matching mechanisms based on efficiency, stability and strategy-proofness.

**3 - Refugee Resettlement via Integer Programming**

Andrew C. Trapp, Worcester Polytechnic Institute, School of Business, 100 Institute Rd., Worcester, MA, 01609, United States, Alexander Teytelboym, Narges Ahani, Tommy Andersson

Hundreds of thousands of refugees are resettled yearly from refugee camps to host countries. Local areas that host refugees are reluctant to open capacity, and most impose tight restrictions on the refugee family types they accept. We model this matching challenge as a 0-1 knapsack variant and explore outcomes-related objectives in the search toward an optimal allocation. Our employment optimization matching problem is embedded within a dynamic software tool that facilitates interactive use to fine-tune the recommended match results.

**4 - How (Not) to Allocate Affordable Housing**

Nicholas A. Arnosti, Columbia Business School, 3022 Broadway, Uris Hall, Rm 402, New York, NY, 10027, United States

We study the dynamic assignment of items to agents. We find that systems with very different descriptions can produce identical outcomes. In particular, a) Independent lotteries are equivalent to a waitlist in which participants lose their position after rejecting an offer, and b) Restricting lottery entry is equivalent to using a waitlist in which participants can reject offers without penalty. Furthermore, we show that there is often a tradeoff between matching (assigning agents to items that are a good fit) and targeting (assigning items to agents with the greatest need).

**■ WA78**

West Bldg 213B

**Transportation Problems with Public Impact**

Sponsored: Public Sector OR

Sponsored Session

Chair: Pinar Keskinocak, Georgia Institute of Technology, Atlanta, GA, 30332, United States

Co-Chair: Amanda Chu, Georgia Tech, Huntsville, AL, 35802, United States

**1 - Data Analysis and Visualization of the Link between Transportation Access and Emergency Health Care**

John Cima, University of Michigan, Amy Cohn, Patrick Carter, Tawanna Dilllahunt

Transportation access can be a significant determinant of health, as it influences access to healthy foods, employment, healthcare, and more. We consider roughly half a million emergency department visits to a major university medical center and compare access to this facility via public versus private transportation. Using travel time to the hospital and other demographic data, we use data visualization techniques to highlight sources of disparity and hypothesize how these disparities impact care and outcomes for patients

**2 - Reducing Bus Transportation Cost through School Start Time Optimization**

Dipayan Banerjee, Northwestern University, Evanston, IL, United States, Liwei Zeng, Karen Smilowitz, Jill Hardin Wilson

We present new models to minimize the number of buses required to complete a set of school bus routes by shifting the start times of the associated schools. Our work extends existing integer programming models by introducing features which reflect realistic facets of public school transportation systems.

**3 - Dynamics of Quality as a Strategic Variable in Complex Food Supply Chain Network Competition: The Case of Fresh Produce**

Anna B. Nagurney, John F. Smith Memorial Professor, University of Massachusetts Amherst, Isenberg School of Management, Amherst, MA, 01003, United States, Deniz Besik, Min Yu

In this paper, we construct a competitive food supply chain network model in which the profit-maximizing producers decide not only as to the volume of fresh produce produced and distributed using various supply chain network pathways, but they also decide, with the associated costs, on the initial quality of the fresh produce. The quality of the fresh produce is captured through explicit formulae that incorporate time, temperature, and other link characteristics. The Nash equilibrium is formulated as a variational inequality problem, for which qualitative and numerical results are provided, with a case study on peaches that includes disruptions in transport.

**4 - School Bus Routing Problem with Fixed Bell Time Windows: Denver Public Schools**

Amanda Chu, Georgia Institute of Technology, Atlanta, GA, United States, Pinar Keskinocak, Monica Villarreal

For this project, we describe the bus route planning process of Denver Public Schools (DPS). Route planning has been challenging for DPS despite commercially available assistance and involves manual readjustment to the routes. This problem was solved using a multi-objective optimization model with Google Map data and parameters to reduce effects of delays integrated into a decision support tool. Initial analysis showed potential decrease in used buses by

15% and in total reposition time and mileage by 25%. Based on the promising results and increased control and flexibility provided by the tool, DPS is integrating the tool into the planning process for the 2018-2019 academic year.

**Wednesday, 10:00AM - 10:50AM****■ KeynoteS – Wednesday**

North Bldg 224

**Keynote: Energy Industry Transformation through Advanced Analytics**

Keynote Session

Chair: Georgia Perakis, Massachusetts Institute of Technology, Cambridge, MA, 02142-1347, United States

**1 - Energy Industry Transformation through Advanced Analytics**

Jorge Calzada, National Grid, Boston, MA, United States

The regulated energy utility industry is in the midst of a massive transformation being driven by several inexorable trends: the growth of distributed energy resources, the desire to transition to a carbon-free economy, the desire of regulators to change the regulatory construct between society and utilities, asset digitization, the speed and costs of computing, and an aging workforce all contribute to an industry in a state of great flux. This presentation will explore how one utility, National Grid, is embracing Advanced Analytics to not only survive these disruptions, but to thrive in the energy landscape of the future.

North Bldg 229

**Keynote: OR and the Transportation Tech Revolution**

Keynote Session

Chair: Pavlo Krokhmal, University of Arizona, Tucson, AZ, 210020, United States

**1 - OR and the Transportation Tech Revolution**

Garrett van Ryzin, Cornell Tech/Lyft, Ithaca, NY, United States

Sparked by the growth of ridesharing startups (Uber, Lyft) - the transportation tech sector has already produced some of the highest valued startups in history. Soon after this initial ridesharing wave, attention turned to autonomous vehicles with significant R&D efforts launched by tech giants (Google, Tesla, Apple), major automakers (GM, Daimler, Ford, FCA), ridesharing companies (Uber, Lyft) and mobility startups (Adaptiv, Nutoonomy, Mobileye). Over the past year, the tech world pivoted yet again to scooters (Bird, Lime) and bikes (Jump, Motivate) - birthing yet another round of billion-dollar startups. In this talk, I examine the technological and economic forces behind this unprecedented wave of innovation and investment in transportation and why it creates an unprecedented opportunity for our field of Operations Research (OR).

**Wednesday, 11:00AM - 12:30AM****■ WB01**

North Bldg 121A

**Joint Session OPT/Practice Curated: Hedging Against Uncertainty in Renewable Energy**

Sponsored: Optimization/Optimization under Uncertainty

Sponsored Session

Chair: Gokce Kahvecioglu, Northwestern University, Evanston, IL, 60208, United States

**1 - Robust Zonal Electricity Markets**

Ignacio Aravena, Lawrence Livermore National Laboratory, Livermore, CA, 94550, United States, Anthony Papavasiliou, Yves Smeers

We propose a consistent framework for modeling zonal electricity markets based on projecting the constraints of the nodal network onto the space of the zonal aggregation. We use the framework to model two zonal market designs and we develop cutting-plane algorithms for clearing these zonal markets while accounting for robustness of zonal exchanges to single element outages. We conduct numerical simulations of the zonal market designs for a realistic instance of the Central Western European system under 768000 different operating conditions. We find that robust zonal markets are unable to anticipate congestion and that they are outperformed by a nodal market design without robustness.



## 2 - Robust Power Dispatch and Renewable Energy Management

Ruiwei Jiang, University of Michigan, Ann Arbor, MI, 48109,  
United States, Hongyan Ma

In this paper, we propose a robust power dispatch approach through incorporating a corrective re-dispatch and integrating active management of renewable energy, which co-optimizes the power pre-dispatch strategies and the admissible ranges of renewable outputs. Case studies on the modified IEEE systems display the effectiveness and scalability of this approach.

## 3 - Risk Averse Energy Storage Optimization for High Penetration of Wind Energy

Juliana Nascimento, Princeton University, Sherrerd Hall,  
Operations Research and Finl Engineering, Princeton, NJ,  
United States, Joseph Durante, Warren B. Powell

We propose a modified stochastic dual dynamic programming (SDDP) method aimed at optimizing energy storage for a set of batteries scattered across the energy grid. With the fine-grained time scale of battery storage, we also have to optimize over hundreds of time periods. We consider a hidden semi-Markov model (HSMM) that accurately reproduces the crossing-time behavior of the wind, which captures the amount of time that actual wind sample paths are above or below the forecast. We show that we can significantly decrease the risk of shortages when we consider our HSMM model coupled with the proposed modified SDDP method over the classical iid stochastic model coupled with a standard SDDP algorithm.

## 4 - Planning Transmission Storage and Generation for Renewable Energy and Carbon Policies Uncertainty

Jing Peng, Johns Hopkins University, 3400 N. Charles Street,  
Baltimore, MD, 21218, United States, Qingyu Xu,  
Benjamin Field Hobbs

Renewable energy policies and carbon policies are reshaping the power system by providing incentives to invest more in renewables and displace coal generation. However, the particular timing and implementations of these policies are uncertain to the power system planners. Due to rapidly dropping costs, the energy storage is becoming an increasingly competitive option. We propose an optimization model to plan energy storage, accounting for its substitution and complementary relations with transmission and generation, to hedge against policy uncertainties in the western interconnection of North America.

## ■ WB02

North Bldg 121B

### Joint Session OPT/Practice Curated: Stochastic Assignment Problem Applications to Healthcare and Network Design

Sponsored: Optimization/Optimization under Uncertainty  
Sponsored Session

Chair: Onur Tavaslioglu, University of Pittsburgh, Pittsburgh, PA,  
United States

## 1 - Stochastic Operating Room Scheduling Under Emergency Arrivals with Integrated Block Assignments

Onur Tavaslioglu, University of Pittsburgh, Houston, TX, 77025,  
United States, Oleg A. Prokopyev, Andrew J. Schaefer

Operating room scheduling for elective procedures is challenging due to the nonlinear structure and stochasticity. In this paper, we model the operating room scheduling problem as a two-stage stochastic mixed integer program with nonlinear objective and chance constraints. We then present a value function reformulation, which converts the mentioned model into a pure binary program. We propose a dynamic programming based approach to calculate the value functions. We compare our approach to a cut generation approximation from the literature. The performance of our approach is better in computational time and it offers optimal solutions.

## 2 - Facility Protection and Network Design when the Effect of Protection is Uncertain

Tanveer Hossain Bhuiyan, Mississippi State University,  
McCain Engineering Building, Room 321, Starkville, MS, 39759,  
United States, Hugh Medal

We study a facility location and network design problem that involves protecting facilities subject to random disruptions where the protection is imperfect, multi-level, and the effect of disruption is imperfect. The goal of our study is to optimally allocate protection resources to the facilities, and construct links in the network to minimize the expected transportation cost. We model the problem as a two-stage stochastic programming with decision dependent uncertainty where the post-disruption capacity states of the facilities depends probabilistically on the resource allocation decision and the disruption intensity. We implement an L-shaped algorithm to solve the model.

## 3 - Chance-constrained Bin Packing Problem with an Application to Operating Room Scheduling

Shanshan Wang, Beijing Institute of Technology, 5 South Street  
Zhongguancun, Haidian District, Beijing, 100081, China  
Shanshan Wang, Northwestern University, Evanston, IL,  
United States, Sanjay Mehrotra, Jinlin Li

We develop a branch-and-cut solution scheme for chance constrained optimization of bin-packing problems with random technology matrices. The problem is to allocate items with random weight to a set of bins with respect to bin size, so as to minimize the total open and allocation cost subjecting to the packing constraints with given probabilistic guarantees. We formulate the integer programs by assuming discrete distributions of random weight. We propose a branch-and-cut framework with several new classes of valid inequalities. Computational study on chance-constrained formulation of surgery assignment problem is conducted to verify the performance of our algorithms.

## 4 - Multi-mode Resource Constrained Project Scheduling with Optional Activities and Uncertain Network Structure

Chrysanthos Gounaris, Carnegie Mellon University, Doherty Hall  
3107, Dept of Chemical Engineering, Pittsburgh, PA, 15213,  
United States, Nikolaos Lappas, Hua Wang

The classical Multi-mode Resource Constrained Project Scheduling Problem (MMRCPSP) is defined upon a fixed directed graph modeling the precedence of activities that have to be executed exactly once in one of their available modes. In practice, however, there are cases where network structure can be altered both by internal strategic decisions as well as uncertain external factors. To that end, we extend MMRCPSP to accommodate flexible network structures that involve recycles and optional activities via the use of propositional logic, and we present a set of new applicable models that are compared extensively across a comprehensive list of benchmark problems.

## ■ WB03

North Bldg 121C

### Risk-averse and Robust Optimization

Sponsored: Optimization/Optimization under Uncertainty  
Sponsored Session

Chair: Alexander Vinel, Auburn University, Auburn, AL, 36832,  
United States

## 1 - Hazardous Materials Routing and Network Design under Uncertainty Considering Risk Equity

Nasrin Mohabbati Kalejahi, PhD Candidate, Auburn University,  
Auburn, AL, United States, Alexander Vinel

Moving hazardous materials raises an inherent risk for public safety. One aspect that has received a significant attention in the literature recently relates to the observation that using a single route repeatedly can lead to an undesirable overload of hazmat risk on specific links of the network and risk inequity. In this work, we study hazmat route planning and network design with consideration of risk equity. We combined the concept of Risk Parity with modern risk functions and developed a two stage risk-reward-diversification framework for optimally selecting routes and distributing the exposure to the risk in a network.

## 2 - Distributionally Robust Optimization with Decision-dependent Ambiguity Set

Nilay Noyan, Sabanci University, Faculty of Engineering and  
Natural Sciences, Orhanli/Tuzla Istanbul, 34956, Turkey,  
Miguel Lejeune, Gabor Rudolf

We introduce a new class of distributionally robust optimization problems under decision-dependent ambiguity sets. In particular, as our ambiguity sets we consider balls centered on a decision-dependent probability distribution. The balls are based on a class of Earth Mover's Distances that includes both the Total Variation Distance and the Wasserstein-1 metric. We also consider a special class of problems where decisions are binary and the inherent randomness is characterized by a set of binary vectors, and develop mixed-integer linear programming reformulations.

## 3 - Adjustable Robust Optimization Applied to a Planning Problem in the Wine Industry

Jorge R. Vera, Catholic University of Chile, Dept of Ind Eng  
Campus San Joaquín, Vicuña Mackenna 4860, Santiago, Chile,  
Rodrigo Cofr

Uncertainty is common in industry and particularly in agriculture, where climate and crop yield are some of the relevant sources. In this work we consider a harvest planning problem in the wine industry, where grapes are harvested and transported to wineries. However, variability in the fermentation process introduces uncertainty in the processing capacity of the winery. Grapes cannot be stored, so harvest planning must take this into consideration. In this work we present a 2 Stage Stochastic approach as well as an Adjustable Robust approach for harvest planning, considering also the potential effect in product quality. We show results of different solution schemes for a real industrial case.

#### 4 - Robust Optimization and Control for Electricity Generation and Transmission

Haoxiang Yang, Northwestern University, 2145 Sheridan Road, Evanston, IL, 60208, United States, David Morton, Chaithanya Bandi, Krishnamurthy Dvijotham

We consider a robust optimization problem for the electric power system under uncertain demand and availability of renewable energy resources. Based on the recently developed convex relaxation schemes for the alternating current optimal power flow (ACOPF) problem, we construct a robust convex optimization problem with recourse. We propose a cutting-plane method with enhancements to solve this problem, and we establish convergence and other desirable properties. Experimental results indicate that our robust convex relaxation of the ACOPF problem can provide a tight lower bound and an acceptable solution for the non-convex robust ACOPF problem.

#### ■ WB04

North Bldg 122A

#### Formulations and Algorithms for MIP

Sponsored: Optimization/Integer and Discrete Optimization

Sponsored Session

Chair: Sahar Tahernejad, Lehigh University, Bethlehem, PA, 18015, United States

##### 1 - Finding Feasible Solutions to Integer Programs with Bounded Integrality Gap in Polynomial Time

Arash Haddadan, Carnegie Mellon University, 5000 Forbes Avenue, Pittsburgh, PA, 15213, United States, Robert D. Carr, Cynthia Phillips

We present a new algorithm for finding a feasible solution for a mixed integer linear program. The algorithm runs in polynomial time and is guaranteed to find a feasible integral solution provided the integrality gap is bounded. The algorithm computes convex decompositions and it provides a suite of integral solutions. The main application of our algorithm is to experimentally evaluate the integrality gap of IP formulations. We apply this technique to several network design problems such as 2-edge-connected subgraph, vertex-cover, and tree augmentation.

##### 2 - A New Integer Programming Formulation of the Graphical Traveling Salesman Problem

Robert D. Carr, University of New Mexico, Albuquerque, NM, United States, Neil Simonetti

In the Traveling Salesman Problem (TSP), a salesman wants to visit a set of cities and return home. There is a cost  $c_{ij}$  of traveling from city  $i$  to city  $j$ , which is the same in either direction for the Symmetric TSP. The objective is to visit each city exactly once, minimizing total travel costs. In the Graphical TSP, a city may be visited more than once, which may be necessary on a sparse graph. We present a new integer programming formulation for the Graphical TSP for sparse graphs.

##### 3 - Two-stage Mixed-integer Stochastic Bilevel Optimization Problems

Sahar Tahernejad, Lehigh University, Bethlehem, PA, 18015, United States, Ted K. Ralphs

Two-stage mixed-integer stochastic bilevel optimization problems (2SMISBLPs) unify the multi-level and multi-stage stochastic optimization problems, while the numbers of decision makers (DMs) and time stages are limited to two, and a subset of variables are constrained to be discrete. The importance of this new framework arises from the fact that in many real-world problems, two DMs (with possibly competing objectives) make the decisions, while the accurate values of some input parameters are unknown at the beginning. In this talk, we describe special cases of 2SMISBLPs and illustrate how the algorithms for these special cases can be integrated to be employed for solving general 2SMISBLPs.

##### 4 - Set Covering Problem with Conflict Constraints

Saeed Saffari, North Carolina State University, Raleigh, NC, 27607, United States, Yahya Fathi

We consider the well-known set covering problem in which we have incompatibilities between certain pairs of columns, i.e., from each conflicting pair at most one column can occur in the optimal subset. We introduce and discuss several classes of valid inequalities and pre-processing techniques for the IP model of this problem, and demonstrate their effectiveness in the context of a branch and cut algorithm.

#### ■ WB05

North Bldg 122B

#### Large-Scale Conic Optimization

Sponsored: Optimization/Linear and Conic Optimization

Sponsored Session

Chair: Neal Parikh, Cornell University, Ithaca, NY, United States

Co-Chair: Brendan O'Donoghue, Google DeepMind, United Kingdom

##### 1 - Chordal Decomposition in Operator-splitting Methods for Sparse Semidefinite Programs

Yang Zheng, University of Oxford, Oxford, United Kingdom, Giovanni Fantuzzi, Antonis Papachristodoulou, Paul Goulart, Andrew Wynn

We employ chordal decomposition to reformulate a sparse SDP into an equivalent SDP with smaller positive semidefinite constraints. In contrast to previous approaches, the decomposed SDP is suitable for the application of first-order methods. We apply the alternating direction method of multipliers (ADMM) to solve decomposed SDPs either in primal, dual or self-dual embedding form. Each iteration of such ADMM algorithms requires a projection onto an affine subspace, and a set of projections onto small PSD cones that can be computed in parallel. All algorithms are implemented in the MATLAB solver CDCS. Numerical experiments on a range of sparse SDPs demonstrate the efficiency of our methods.

##### 2 - Globally Convergent Type I Anderson Acceleration for Non-smooth Fixed Point Iterations

Junzi Zhang, Stanford University, Stanford, CA, 94305, United States, Brendan O'Donoghue, Stephen P. Boyd

We consider the application of the type-I Anderson acceleration to solving general non-smooth fixed-point problems. By interleaving with safe-guarding steps, and employing a Powell-type regularization and a re-start checking for strong linear independence of the updates, we propose the first globally convergent variant of Anderson acceleration assuming only that the fixed-point iteration is non-expansive. We show by extensive numerical experiments that many first order algorithms can be improved with the proposed algorithm. Our proposed method of acceleration is being implemented in SCS 2.0, one of the default solvers used in the convex optimization parser-solver CVXPY 1.0.

##### 3 - On Robustness and Scalability of Semidefinite Relaxation Techniques for Optimal Power Flow

Anders Eltvad, DTU, Denmark

Semidefinite relaxation techniques have shown great promise for nonconvex optimal power flow problems. However, a number of independent numerical experiments have led to concerns about scalability and robustness of existing SDP solvers. To address these concerns, we investigate some numerical aspects of the problem and compare different state-of-the-art solvers. Our results demonstrate that large problem instances with a positive semidefinite cone of order up to 25,000 can be solved reliably and to reasonable accuracy within minutes.

##### 4 - Deep Belief Network with Surrogate Optimization for Cyanobacterial Risk Prediction

Peng Jiang, Shanghai Jiao Tong University, Shanghai, 200240, China, Xiao LIU, Karina Yew Gin

Cyanobacterial blooms are threatening human health and the sustainability of freshwater resources. For situations with massive data, deep learning models emerge to be workable solutions for predicting cyanobacterial risks. However, the high-dimensional hyperparameters of such a model are hard to calibrate. Traditional trial-and-error methods for tuning them are computationally expensive. We propose a surrogate optimization-assisted deep belief network model to predict cyanobacterial risks in a data-driven manner. Therein, a modified mixed-integer surrogate optimization algorithm is hybridized into the model. Finally, a real case is employed to demonstrate its effectiveness.

## ■ WB06

North Bldg 122C

**Interface of Consumer Behavior and Retail Operations**

Sponsored: Manufacturing &amp; Service Oper Mgmt

Sponsored Session

Chair: Stanley Lim, University of Cambridge, Cambridge, United Kingdom

Co-Chair: Annibal Sodero, University of Arkansas, Fayetteville, AR, United States

**1 - Operational Execution and POP Display Effectiveness: Evidence from Adoption of an IoT Technology**

Ioannis Stamatopoulos, University of Texas at Austin, McCombs School of Business, 2110 Speedway, B6000 Austin, TX 7870, Austin, TX, 78705, United States, Ashish Agarwal, Jacob Zeng

POP displays are structures containing inventory outside of regular shelving. They are meant to be visually stimulating, are placed in prominent positions in retail stores, and their purpose is to excite spontaneous purchases. POP displays are perceived by suppliers to be highly effective and they invest in them heavily. However, poor operational execution is reducing their otherwise high effectiveness. We are interested in quantifying the extent of the problem, as well as exploring whether an IoT technology can improve operational execution.

**2 - Using Transactions Data to Improve Consumer Returns Forecasting**

Guangzhi Shang, PhD, Florida State University, Erin Cassandra McKie, Mark Ferguson, Michael Galbreth

Although an accurate returns forecast is the preliminary input into many decision support tools for managing returns, the development methods in this area received relatively little attention as compared with sales forecasting. We propose a new approach and benchmark its performance against a number of existing methods using two real world datasets.

**3 - Free Shipping is Not Free: A Data-driven Model to Design Free-shipping Threshold Policies**

Joseph Xu, PhD, Carnegie Mellon University, Gerard P. Cachon, Santiago Gallino

We provide a data-driven analytical model to (i) assess the profitability of an online retailer's free shipping threshold policy, and (ii) offer recommendations to determine a suitable level of free shipping threshold policy to maximize profit. The model accounts for various aspects of customer behavior, such as strategically adding items to shopping basket to receive free shipping and changing the quantity of item returned. We calibrate our model to data from an online apparel retailer and find that its decision to offer a lower free shipping threshold reduce its profitability considerably.

**4 - An Analysis of Shopping Behaviour at Warehouse-club Stores and its Store-network-density Implications**

Stanley Lim, University of Cambridge, Tempe, United Kingdom, Arizona State University, Tempe, AZ, United States, Elliot Rabinovich, Sungho Park, Minha Hwang

Warehouse club (WC) retailers have historically relied on low-density store networks as a source of competitive advantage. Despite their significant presence in the retail sector, we are aware of no empirical studies examining how significant this source of competitive advantage is for them. We use a quasi-natural experiment with households' subscriptions to Costco stores as a treatment mechanism to contrast members' purchasing behaviors at Costco stores against changes in behaviors at non-WC stores. We show that members' weekly mileage accumulated per visit, dollar spent per visit, and dollar spent per mile to Costco stores exceeds by 7.4%, 29% and 20%, respectively, relative to non-WC stores.

**5 - Inventory Allocation for Multi-channel Drop-shippers**

Annibal Sodero, PhD, University of Arkansas

Drop-shipping, an arrangement in which retailers sell products online and the products are sent directly from the vendors' facilities to the point of consumption, is growing in importance. For vendors of seasonal products who drop-ship but also sell wholesale to their retail customers, there are many questions left regarding inventory allocation and deployment, because they need to consider the usual tradeoffs between inventory costs and service levels. For instance, when should they segregate or keep a single pool of inventory to satisfy demand? When and whom to release inventory in the wholesale channel? We simulate scenarios to provide answers to those questions, among others.

## ■ WB07

North Bldg 123

**Models and Methods for Network Design**

Sponsored: Optimization/Network Optimization

Sponsored Session

Chair: Angelika Leskovskaya, Southern Methodist University, Caruth Hall 3145 Dyer Street, Suite 372, Dallas, TX, 75275, United States

**1 - Robust Service Network Design under Demand Uncertainty: An Exact Approach**

Mingyao Qi, Associate Professor, Tsinghua University, Room E204A, Shenzhen, 518055, China, Zujian Wang

Freight forwarding companies are faced with difficulties in handling uncertainties, especially demand uncertainty under the circumstances of no enough historical data or accurate forecasting approach. In this paper, we propose a two-stage robust optimization method for service network design under demand uncertainty. We employ probability-free uncertainty sets to describe the possible scenarios, and implement a column-and-constraint generation algorithm to solve the proposed two-stage robust models exactly and efficiently. Numerical results indicate that the proposed algorithm outperforms the Benders decomposition method in both solution quality and computational time.

**2 - Service Network Design with Node Capacity with Application in Parcel Delivery**

Huan Jin, MIT Global SCALE Network, 462 Wen Yuan Road, Bldg 3, Rm 504, Ningbo, 315100, China

The rapid development of e-commerce has made the explosion of online shopping. A large part of the urban logistics parcels come from online e-commerce orders. We consider a service network design for parcels urban logistics with node capacity. The node capacity is the space/quantity limit of holding resources (drivers, vehicles) at terminals. The node capacity, for instance, the parking limit at terminals, varies by the time of a day or the day of a week. We introduce a general formulation and design a Branch-and-Price method with heuristic algorithm to provide good quality solution of the formulation. A comprehensive analysis of the formulation and algorithm is given based on the numerical results.

**3 - Integer Programming Models for Freight Logistics Service Network Design with Tree Constraints**

Ira M. Wheaton, Postdoctoral Fellow, Georgia Institute of Technology, 755 Ferst Drive, NW, Atlanta, GA, 30332, United States, Natasha Bolland

Less-than-truckload (LTL) service providers often, in practice, route shipments so as to satisfy tree constraints: at any node in their service network, all shipments that are handled at that node and that have the same destination must be routed via the same outgoing arc. Although the design of LTL service networks has been widely studied, tree constraints have generally been ignored. Here, we consider integer programming (IP) models for the service network design problem with tree constraints. We formulate and analyze multiple IP models and report computational results.

**4 - A Mathematical Programming Model with Equilibrium Constraints for Competitive Closed Loop Supply Chain Network Design**

Qiang Qiang, Penn State University, Management Division, 30 E. Swedesford Rd, Malvern, PA, 19355, United States, Yuxiang Yang, zuqing huang

A firm sets up his facilities including manufacturing/remanufacturing plants and distribution/collection centers, incorporating an existing CLSC network. The entering firm has to compete with the existing firms in the existing network. The entering firm behaves as the leader of a Stackelberg game while the existing firms in the existing network are followers. We use a CLSC network equilibrium model to capture the existing firms' reaction. A mathematical programming model with equilibrium constraints is developed for this competitive CLSC network design problem. Numerical examples and the related results are studied for illustration purpose.

**5 - Data-driven Transit Network Design**

Julia Y. Yan, Massachusetts Institute of Technology, 77 Massachusetts Avenue, Cambridge, MA, 02139, United States, Dimitris Bertsimas, Yee Sian Ng

Modern transit agencies have to provide reliable and equitable transit services in the face of declining ridership and tight financial budgets. In 2012, this analysis was performed for MBTA bus services, involving a tedious procedure of "manual branch-and-bound". Instead, we provide a unified approach that optimally selects a subset of the routes to maximize ridership, while satisfying coverage requirements. It solves within minutes for networks with hundreds of services across 164 municipalities. In comparisons against a greedy heuristic, our approach is able to double the transit ridership while satisfying regulatory requirements under tight financial constraints.



## 6 - Extreme-point Search Heuristics for Solving Fixed-charge Generalized Network Problems Using Parametric Ghost Image Process Approach

Angelika Leskovskaya, PhD Candidate, Southern Methodist University, Caruth Hall 3145 Dyer Street, Suite 372, Dallas, TX, 75275, United States, Richard S. Barr

While researchers have studied generalized network flow problems extensively, the powerful addition of fixed charges on arcs has received scant attention. This work describes network-simplex-based algorithms that efficiently exploit the quasi-tree basis structure of the problem relaxations, proposes heuristics that utilize a tabu search and a progressive modification of a parameterized objective function for fixed-charge transportation problems, extends the parametric GIP approach to fixed-charge transshipment problems, and presents computational comparisons with commercial solution alternatives.

## ■ WB08

North Bldg 124A

## Stochastic Optimization Methods and Approximation Theory in Machine Learning I

Sponsored: Optimization/Nonlinear Programming  
Sponsored Session

Chair: El Houcine Bergou, INRA-KAUST, Jeddah, Saudi Arabia

Co-Chair: Aritra Dutta, INRA-KAUST, Thuwal, Saudi Arabia

### 1 - Robust PCA by Manifold Optimization

Teng Zhang, University of Central Florida, Orlando, FL, United States

Robust PCA is a widely used statistical procedure to recover an underlying low-rank matrix with grossly corrupted observations. This work considers the problem of robust PCA as a nonconvex optimization problem on the manifold of low-rank matrices and proposes two algorithms based on manifold optimization. It is shown that, with a properly designed initialization, the proposed algorithms are guaranteed to converge to the underlying low-rank matrix linearly. Compared with a previous work based on the factorization of low-rank matrices the proposed algorithms reduce the dependence on the condition number of the underlying low-rank matrix theoretically. Simulations and real data examples confirm the competitive performance of our method.

### 2 - Kolmogorov Representation and Deep Learning

Xin Li, University of Central Florida, 4000 Central Florida Blvd, Orlando, FL, 32816, United States

In essence, Kolmogorov's representation theorem states that every continuous function of high dimensional space is completely determined by a function of a single variable. The drawback is that the single variable function used in the representation can be highly non-smooth and hard to compute. On the other hand, Barron proved an approximation theorem with a universal convergence guarantee. This talk will explore the connection between the ideas of Kolmogorov and Barron with the aim at a possible understanding of deep learning through a form or structure of function approximation that is not as rigid as Kolmogorov's representation but "deeper" and more inclusive than Barron's approximation.

### 3 - The Multiple Shades of Dropout for both Discriminative and Generative Deep Neural Networks

Boqing Gong, Principal Researcher, Tencent AI Lab, Seattle, WA, United States

Dropout, which independently zeros out the outputs of neurons at random, has become one of the most popular techniques in training deep neural networks due to its simplicity and remarkable effectiveness. This talk reveals multiple shades of dropout for both discriminative and generative deep neural networks. The first half of the talk focuses on the discriminative models and presents an improved version of the dropout. In the second half of the talk, I will provide a new perspective for understanding dropout under the context of deep generative neural networks. Despite being impactful on a variety of problems and applications, the generative adversarial nets (GANs) are remarkably difficult to train. In particular, our approach gives rise to the inception score of more than 5.0 with only 1,000 CIFAR-10 images and is the first that exceeds the accuracy of 90% on the CIFAR-10 dataset using only 4,000 labelled images, to the best of our knowledge.

## ■ WB10

North Bldg 125A

## Joint Session MSOM/APS: Design and Analysis of Emerging Service Systems

Sponsored: Manufacturing & Service Oper Mgmt  
Sponsored Session

Chair: Mohammad Delasay, Stony Brook University, Stony Brook, NY, 11794, United States

Co-Chair: Sherwin Doroudi, University of Minnesota, Minneapolis, MN, 55455, United States

### 1 - Signaling in Online Retail: Efficacy of Public Signals

David Lingenbrink, Cornell University, Ithaca, NY, 14850, United States, Krishnamurthy Iyer

We study an online retail setting, where strategic customers seek to purchase an item with a finite inventory in one of two time periods. Only the firm knows the inventory and demand, and seeks to persuade customers to buy in the more expensive first time period through signaling. We analyze both public and private signaling, and find that, with homogeneous customers, it is optimal to signal publicly: the firm cannot raise its revenue by sending a different private signal to each customer. However, when customers are heterogeneous, we find examples where private signaling outperforms public.

### 2 - Coffee Shop Operations with Mobile Ordering

Kang Kang, University of Minnesota, Minneapolis, MN, 55455, United States, Mohammad Delasay, Sherwin Doroudi

Mobile ordering is becoming popular in the world of coffee shop, fast food or restaurants. Our work examines the operations of a coffee shop where some customers can use a mobile app to skip the ordering and payment queue. Using queueing theory, we explore the impact of mobile customers on walk-in customers and vice versa across a variety of service policies.

### 3 - A Queueing Model and Analysis for Autonomous Vehicles on Highways

Neda Mirzaeian, Carnegie Mellon University, Pittsburgh, PA, United States, Soo-Haeng Cho, Alan Scheller-Wolf

Autonomous vehicles (AVs) have a potential to significantly improve highway congestion, since these vehicles are able to maintain smaller inter-vehicle gaps, and travel together in larger platoons (or batches) than human-driven vehicles (HVs). We model a highway segment as a queueing system, and analyze two policies: the designated-lane policy (designating one lane to AVs) and the integrated policy (allowing both AVs and HVs in any lane). After calibrating our model to data, we show that, depending on the proportion of AVs and the highway load, either of these policies can outperform the other.

### 4 - Assignment of Jobs to Servers under Interference

Scott Votke, Stony Brook University, Stony Brook, NY, United States, Jazeem Abdul Jaleel, Mohammad Delasay, Sherwin Doroudi, Anshul Gandhi

In cloud computing, interference is a major drawback to latency sensitivity and performance analysis. In this paper, we study an M/M/c queueing system where the individual servers are subject to periods of interference, which result in lower than normal service rates. A controller decides whether to send incoming jobs to an available server or to the queue. We assume that the length of interference for all servers are i.i.d. exponentially distributed random variables. By modeling such a system as a Markov decision process, we investigate the optimal policy on how to route incoming jobs.

## ■ WB11

North Bldg 125B

## Joint Session MSOM/Practice Curated: Ride-sharing Services Research at Didi Chuxing

Sponsored: Manufacturing & Service Oper Mgmt  
Sponsored Session

Chair: Zhixi Wan, DiDi Chuxing, Beijing, China

### 1 - Modelling of Driver Supply Behaviour in On-demand Shared Transportation Platforms

Hai Wang, Singapore Management University, Room 5023, School of Information Systems, 178902, Singapore, Hao Sun, Zhixi Wan, Guobin Wu, Qun Li

With the popularization of ride-sharing services, drivers working as freelancers on ride-sharing platforms can design their schedules flexibly. They make daily decisions regarding whether to participate in work, and if so, how many hours to work. Driver's extra income, participation cost, and maximum allowed working time affect these decisions. We incorporate these features into classical theory of labour economics and propose a theoretical model to describe how drivers make working decisions on the shared platform. We characterize the labour supply pattern of participation, working hours, extensive and intensive margin elasticity on the platform and compare with the traditional taxi.

## 2 - Carpooling Service: Social Welfare and Pricing Strategies

Shuanglong Wang, University of Illinois at Urbana-Champaign, IL, United States, Zhixi Wan

This paper empirically studies the social welfare created by carpooling service on the ride-hailing platform over the counterfactual situation that only the regular-express service is provided. We use the data from Didichuxing, a leading ride-hailing platform in China, to estimate a nested logit model describing riders' choice behavior over regular express, carpooling and outside options. We also derive a carpooling pricing scheme for optimizing the social welfare and investigate its sensitivity properties. The results show that the carpooling service is advantageous in increasing riders' surplus and provides an alternative solution to supply-demand matching other than surge pricing.

## 3 - The Efficiency of a Dynamic Decentralized Two-sided Matching Market

Chenyu Yang, University of Rochester, NY, United States, Zhixi Wan, Xiao Liu

This paper empirically studies a decentralized dynamic matching market. We use data from a leading ride-sharing platform in China to estimate a continuous time dynamic model of search and match between drivers and passengers. In counterfactual simulations, we assess the efficiency of the decentralized market and examine how centralized algorithms may improve welfare. Compared with the equilibrium in the decentralized market, centralized algorithms can increase both the match quality and the number of matches by making matches less frequently and matching agents more assortatively.

## 4 - Balancing Supply and Demand: Queuing versus Surge Pricing Mechanisms

Zhixi Wan, DiDi Chuxing, Beijing, China, Yueyang Zhong, Max Shen

One of the most challenging market-making problem faced all ride-sharing platforms is to deal with the scenarios with high demand and limited supply. Dynamic pricing mechanisms, often called surge pricing, have been used by all major platforms. This talk describes a new mechanism adopted by Didi Chuxing, which uses virtual queuing mechanisms to allocate car supply to waiting riders. It then compares the queuing with the dynamic pricing mechanism in metrics of efficiency, fairness, consumer surplus, etc.

## ■ WB12

North Bldg 126A

## Marketing I

Contributed Session

Chair: Shelly Rathee, University of Utah, 201 Presidents Cir, Salt Lake City, UT, 84112, United States

## 1 - Behavior Based Pricing with Heterogeneous Customer Fairness Concern

Runyu Tang, PhD Student, Tsinghua University, Haidian District, Beijing, 100084, China

Behavior-based pricing (BBP) strategy is getting popular with the development of big data technology. However, the different prices among customers also stir displeasure and may bring a loss of loyalty. Fairness is an essential issue when making BBP pricing decisions. Using an analytical model with heterogeneous fairness concern, I find a monopoly BBP seller's optimal profit and price gap decrease with stronger fairness concern. When there are two competing sellers with only one of them adopts BBP strategy, the optimal profit for the BBP seller first decreases then increases with customers fairness concern. What's more, the BBP seller should always charge the new customers with a lower price.

## 2 - The Effect of Delightful Surprise on Consumer Behavior in the Real World: A Large-scale Field Study

Peng-Chun Chen, PhD Student, National Taiwan University, 6F, No.45, Sec. 5, Zhongxiao E. Rd., Xinyi Dist, Taipei, 110, Taiwan

Previous research has established a causal relationship between delightful surprise and consumer satisfaction. However, little evidence in the real world has been provided to verify this effect. In this paper, several field studies have been conducted to test the relationship. We collaborate with an online wine e-commerce platform, manipulating the degree and the content of surprise gifts and measuring customers' satisfaction and the repurchasing behavior afterwards. Our current findings suggest that surprise gifts promote subjects' satisfaction in a large-scale, real-world setting.

## 3 - Consumer Choice under Limited Attention When Alternatives Have Different Information Costs

Frank Huettner, ESMT Berlin, Schlo platz 1, Berlin, 10407, Germany, Tamer Boyaci, Yalcin Akcay

Since information acquisition is costly, consumers trade off the value of better information against its cost and make their product choices based on imperfect information. We model this decision using the rational inattention approach and describe the rationally inattentive consumer's choice behavior when he faces alternatives with different information costs. We find that non-uniform info costs can have a strong impact on product choice, creating situations where it is

disadvantageous for the seller to provide easy access to information or where adding an inferior product increases the market share of another product. We discuss how our framework can be empirically estimated from choice data.

## 4 - Modeling Dynamics in Equity-based Crowdfunding

Chul Kim, Assistant Professor, Baruch College, CUNY, New York, NY, United States, Pallassana K. Kannan, Michael Trusov, Andrea Ordanini

We investigate dynamics characterizing an equity-based crowdfunding: stagnation, gradual increase, and acceleration. We develop a dynamic structural model to accommodate active social interactions among forward-looking investors to capture the contrasting dynamics within a unified framework. We analyze individual investment and network data from a crowdfunding platform, Sellaband. We find that the proposed model shows very good predictive performance. Using counterfactuals, we find the largest possible goal and the smallest possible proportion of profit sharing that maximize the chance of success and the fund raised.

## 5 - Impact of Structural Changes on Price Markups in Food Retail Sector

Lauren Chenarides, Assistant Professor, Arizona State University, 7231 E. Sonoran Arroyo Mall, San Tan 235D, Mesa, AZ, 85212, United States, Mahalingam Dhamodharan

We examine the effect of mergers and acquisitions in the food retail sector on price markups. Using store-level retail and defense commissary scanner data, we calculate price markups for nationally branded products at grocery store chains across the U.S. Low markups observed in concentrated markets due to a merger implies a realization of cost efficiencies for retailers, whereas high markups in similar markets post-merger suggest a gain in retailer market power. We use a diff-in-diff model to identify a causal effect of concentration on retail markups that explain these opposing outcomes and their implications.

## 6 - The Influence of Vague and Precise Waiting Information on Perception of Waiting Time

Shelly Rathee, PhD Candidate, University of Utah, Salt Lake City, UT, United States, Arul Mishra, Himanshu Mishra

Majority of patients consider waiting period as often the worst part of doctor's visit. The type of waiting information provided to patients can take different forms, with different degree of precision. We demonstrate that consumers estimate lower time perception with vague compared to precise waiting information. We employ "take-a-number" queuing system to operationalize vague waiting information with alphanumeric tokens and precise waiting information with numeric tokens and examine how these waiting information influence time perception and patient's satisfaction. We test our predictions across two field studies at a hospital and one controlled lab study.

## ■ WB13

North Bldg 126B

## Practice- Supply Chain Management

Contributed Session

Chair: Ting Ji, University of Science and Technology of China, 1129 Huizhou Ave, Baohe Qu, Hefei Shi, Anhui Sheng, 230000, China

## 1 - Optimal (z, Z)-type Contracts for Vendor-managed Inventory

Jun-Yeon Lee, Associate Professor, California State University, Northridge, CA, 91330, United States, Richard Cho

We examine (z, Z)-type contracts for vendor-managed inventory (VMI) between a supplier and a retailer from the retailer's perspective. A (z, Z) VMI contract specifies minimum and maximum inventory levels and their corresponding under- and over-stocking penalties. We provide the optimal (z, Z) VMI contract for the retailer and the corresponding optimal replenishment decisions for the supplier and show that the optimal (z, Z) VMI contract can coordinate the supply chain under mild conditions. We also examine a VMI contract with stockout penalty and holding-cost sharing, which is a special type of (z, Z) contract, and find that it may perform well compared with the optimal (z, Z) VMI contract.

## 2 - Theory of Constraints Replenishment Solution for Managing Distribution of Perishable Items

Harshal Lowalekar, Associate Professor, Indian Institute of Management-Indore, Prabandh Shikhar, Rau-Pithampur Road, Indore, 453331, India

We develop an analytical model to study the performance of the TOC's replenishment solution in the context of perishable item supply chains. A setting with one producer and one retailer is considered. The retailer follows an order up to level policy with fixed time interval between two consecutive orders. The items are issued at the retailer's end in a random sequence. The analytical model shows that the TOC's replenishment solution will significantly increase the profits of both the producer and the retailer. The product variety and availability at the retailer will increase while the inventory of existing items will decrease due to the TOC approach.

### 3 - Research on Supplier Selection in Logistics Service Supply Chain of China Railway Express Based on Improved DEA Method

Yinying Tang, Southwest Jiaotong University, Chengdu, China,  
Qinglin Li, Qiyuan Peng, Yang Ge, Jingru Ren

In this paper, a new framework and a new method are proposed to do the supplier selection in logistics service supply chain of CHINA RAILWAY Express (CRE). Firstly, considering CRE's actual needs, we analyze the basic process of CRE selecting logistics supplier. Secondly, considering the demand & supply characteristics of the freight market between China and Europe, a new selection framework containing service quality, service price, service capacity and cooperation risk as second-level indicators is given. Thirdly, considering the uncertainty of CRE's international operation, the improved DEA (data envelopment analysis) Model is proposed and solved to evaluate and select suppliers.

### 4 - Analysis of a Manufacturer Issuing Free Gift Cards

Yuefeng Li, University of Electronic Science and Technology of China, School of Management of Economics, West Hi-Tech Zone, Chengdu, 611731, China, Jingming Pan, Xiaowo Tang

Manufacturers offer "free gift cards to consumers who buy the particular product. We structure a model of such gift card promotion in a two-product supply chain. It includes the manufacturer who plans to sponsor gift card promotion and takes the gift card cost, another manufacturer who is passively involved in the promotion and a retailer who sells the two products to consumers. The result shows that the two products are complementary with respect to consumers' demand in the promotion. Moreover, the gift cards have a cannibalization effect on the retailer and a spillover effect on the passive manufacturer. Furthermore, we offer a straightforward strategy which could lead to a win-win-win situation.

### 5 - Supply Chain Coordination with Sales Effort under Cap-and-Trade Regulation

Ting Ji, University of Science and Technology of China, Hefei, China

This paper explores the production decision and the sales effort level in a make-to-order supply chain consisting of a manufacturer and a retailer under cap-and-trade regulation. We explore the supply chain coordination with wholesale price and cost sharing contracts. First, as the marginal sales effort cost increases, the retailer's profit firstly increases and then decreases, while the monotonicity of the manufacturer's profit depends on the cap. Second, both wholesale price and cost sharing contracts can coordinate the supply chain. Third, cap-and-trade regulation has a positive effect on supply chain coordination with the two contracts.

## ■ WB14

North Bldg 126C

### Choice Modeling in Online Platforms

Sponsored: Manufacturing & Service Oper Mgmt/Service Operations

Sponsored Session

Chair: Heng Zhang, Marshall School of Business, Bridge Memorial Hall - BRI 401, 701 W. Exposition Boulevard, Los Angeles, CA, 90007, United States

Co-Chair: Negin Golrezaei, Yale School of Management, Massachusetts Institute of Technology, 30 Memorial Dr, Cambridge, MA, 02142, United States

### 1 - Dynamic Learning in Assortment Selection: A Thompson Sampling Approach

Vashist Avadhanula, Columbia University, 3022 Broadway, 4th Floor West, New York, NY, 10027, United States, Assaf Zeevi, Shipra Agrawal, Vineet Goyal

We consider a dynamic assortment selection problem, where in every round the retailer offers a subset (assortment) of  $N$  substitutable products to a consumer, who selects one of these products according to a multinomial logit (MNL) choice model. The retailer observes this choice and the objective is to dynamically learn the model parameters, while optimizing cumulative revenues over a selling horizon of length  $T$ . We present an approach to adapt Thompson Sampling to this problem and show that it achieves near-optimal regret as well as attractive numerical performance on real world data.

### 2 - An Optimal Assortment for Complements

Xi Shan, University of Texas at Dallas, Richardson, TX, 75080, United States, Dorothee Honhon, Suresh P. Sethi, Chenglin Zhang

Using complements is common practice in assortment planning: Restaurants offer meals with drinks or a music environment, and even allow consumers to bring their own wine. Department stores use one category as complement to the other categories to stimulate purchases. We consider complements in the canonical assortment model (van Ryzin and Mahajan 1999) wherein a newsboy stimulates purchases by offering complements. We show that with complements the retailer uses lower variety and achieves higher profit under certain conditions. We obtain

the Nash equilibrium for category managers in the category management problem and demonstrate the coordination mechanism.

### 3 - Assortment Optimization for an Omnichannel Retailer with Features-based Value Boosts and Discounts

Venus Lo, Cornell University, 206 Rhodes Hall, Cornell University, Ithaca, NY, 14853, United States, Huseyin Topaloglu

We consider a retailer who sells online and in a physical store offline. Customers have initial product valuations, but boost/discount values if they observe under/over-hyped product features in-store. The retailer selects an assortment to offer in-store to maximize expected revenue while managing customers' valuation. Our model organizes products on a tree so that a leaf is a product and a non-leaf vertex is a feature common to leaves in its subtree. Online and offline customers have different consideration sets but both adjust valuations based on the offline assortment. This problem is NP-hard and we present a FPTAS, which performs much better than its theoretical guarantee under computation.

## ■ WB15

North Bldg 127A

### Queueing Games

Sponsored: Applied Probability

Sponsored Session

Chair: Dongyuan Zhan, University College London, London, United Kingdom

### 1 - Invite Your Friend and You'll Move Up in Line: Optimal Design of Referral Priority Programs

Luyi Yang, Johns Hopkins University, 100 International Drive, Baltimore, MD, 21202, United States

In a referral priority program, existing customers on a waitlist for products or services (e.g., mobile apps) can invite their friends to also sign up so that they can jump up in line and get early access. Firms vary in the amount of priority incentives they give, which begs the question of what the optimal program should be. We take a mechanism design approach combined with the achievable region method to this question. Our unifying framework subsumes different schemes used in practice (namely, FIFO, full priority, partial priority, and strategic delay) as special cases and characterizes the conditions under which each scheme is optimal.

### 2 - An Equilibrium Analysis of a Multiclass Queue with Endogenous Abandonments in Heavy Traffic

Xiaoshan Peng, Indiana University, Kelley School, Bloomington, IN, United States, Baris Ata

We study a multiclass queueing system with endogenous abandonments where congestion affects customers' abandonment behavior and vice versa. In the abandonment model, customers take the virtual waiting time distribution as given. Customers are forward looking and make wait or abandon decisions dynamically to maximize their expected discounted utilities. The queueing model takes the customers' abandonment time distribution as an input and studies the resulting virtual waiting time distribution. We show that there exists a unique equilibrium in which the customers' abandonment time and the virtual waiting time for the various classes are consistent in the two models.

### 3 - Service Pricing when Customers Collude

Chenguang (Allen) Wu, Hong Kong University of Science and Technology, Clear Water Bay, Hong Kong, Chen Jin, Senthil Veeraraghavan

Customers' strategic behavior of service procurement is typically modeled by assuming that customers are rational individuals. However, the understanding of customers' behavioral heterogeneity and the resulting implication on the service provider's operational problems is lacking. In this paper, we model the behavioral heterogeneity of customers by considering two customer segments, individual and group customers, who are endowed with different decision structures. Our results explain the operational incentive of a common practice in service systems: group customers receive special rates for service and enjoy a high priority in the admission line.

### 4 - Harnessing the Double-edged Sword: Information Disclosure on Ride-hailing Platforms

Dongyuan Zhan, University College London, School of Management, Gower Street, London, WC1E 6BT, United Kingdom, Leon Yang Chu, Zhixi Wan

We consider a ride-hailing platform that provides free information service to taxi drivers. Upon receiving a rider's request, the platform broadcasts the rider information to the idle taxi drivers, who may accept or decline the request based on the customer's profitability. The first driver who accepts the request gets the ride. If no driver accepts it then the rider leaves. As a result, information disclosure is a double-edged sword for drivers' profits: they may take more profitable rides via inefficient idling. We study the profit implication of this information disclosure, and propose a simple broadcast policy that can achieve close to the first best when the system is large.



#### 5 - Optimal Staffing under Endogenous Arrivals with Heterogeneous Customer Time-of-service Preferences

Yang Li, Chinese University of Hong Kong, 12 Chak Cheung Street, Cheng Yu Tung Building, Hong Kong, Hong Kong, Philipp Afeche

The service operations literature usually treats arrivals as exogenous processes. However, arrival processes may be endogenous in many settings. That is, customers may account for system congestion in choosing their time of service. We propose an equilibrium model that captures how rational customers with heterogeneous preferences decide their time-of-service. We also study the optimal staffing policies, taking into account customers' time-of-service choices.

#### ■ WB16

North Bldg 127B

#### Transitions toward Sustainable Energy, Food, and Living

Sponsored: Manufacturing & Service Oper Mgmt/Sustainable Operations

Sponsored Session

Chair: Owen Wu, Indiana University, Bloomington, IN, 47405, United States

Co-Chair: Yangfang Zhou, Singapore Management University, Singapore, 178899, Singapore

#### 1 - Kicking Ash: Who (or What) is Winning the War on Coal

David F. Drake, Harvard Business School, Morgan Hall 425, Boston, MA, 02163, United States, Jeffrey York

Power generators throughout the U.S. have shed coal capacity at an unprecedented rate over the past several years. Multiple stakeholders have claimed credit - natural gas executives, policy makers, renewables advocates, and environmental NGOs. Through a survival analysis, we explore the extent to which each has impacted the expected life of coal-fired power generating units.

#### 2 - Greenest Grocer: Online or Offline?

Ekaterina Astashkina, INSEAD, Boulevard de Constance, Fontainebleau, 77305, France, Elena Belavina, Simone Marinesi

We compare environmental differences of traditional and online grocery retail channels. We build and calibrate the model that captures household food-buying patterns and the shopping mode choice. We find that, in high store density cities, the development of an online outlet is more efficient in reducing environmental impact in contrast to increased store density. In particular, online shopping attracts households for whom offline is least convenient — such households have the worst impact: they build up more inventories and travel longer distances. Higher store density, in turn, impacts households in a less targeted fashion and, thus, is more efficient only in very low store density scenarios.

#### 3 - Electricity Pricing with Limited Consumer Response

Fariba Farajbakhsh Mamaghani, University of Texas at Dallas, 800 West Campbell Road SM 30, Richardson, TX, 75080, United States, Saed Alizamir, Shouqiang Wang

Matching demand with supply has been a key challenge in operating residential electricity markets. Existence of exogenous random shocks (e.g., outdoor weather condition) and consumer's limited capability in adjusting their household appliance's settings on the other hand lead utility firms face stochastic demand functions which is not well understood in the literature. In this paper, we construct a demand model to explicitly account for such limited consumer response to changes in exogenous random shocks and We fully characterize the firm's optimal price.

#### 4 - Plugged in at the Right Time? Managing Electrical Vehicles Charging

Owen Wu, Indiana University, Kelley School of Business, 1309 E. 10th Street, Bloomington, IN, 47405, United States

As electric vehicles (EV) increasingly penetrate the electrical grid, new business models emerge to reduce the cost of charging EV batteries. We analyze how cost savings depend on the time windows that EVs are plugged in and the charging amount required by customers. We consider setting appropriate prices for the EV charging, in order to change customers' charging demand to maximize the cost savings.

#### ■ WB17

North Bldg 127C

#### Data-Driven Supply Chain Strategies

Sponsored: Manufacturing & Service Oper Mgmt/Supply Chain

Sponsored Session

Chair: Yun Zhang, Massachusetts Institute of Technology, 77 Massachusetts Ave, E18, Cambridge, MA, 02139, United States

#### 1 - Value of Analytics in Inventory Systems

Li Wang, Massachusetts Institute of Technology, 77 Massachusetts Ave, Cambridge, MA, 02139, United States, Jussi Keppo, David Simchi-Levi

We study the trade-off between holding safety stock and deploying data analytics for a retailer facing demand uncertainty. In Newsvendor models, safety stock is used to mitigate the risk of stockouts due to demand uncertainty. However, the demand risk can be reduced by investing in data analytics that creates more accurate demand forecasts and this way lowers the need of safety stock. We solve this joint problem of optimal quantity of analytics and safety stock, and study the comparative statics of the model. For instance, we show that the lower the cost of analytics is, the lower the safety stock.

#### 2 - Distributionally Robust Dynamic Inventory Management with Bank Finance

Zhenzhen Yan, Assistant Professor, Nanyang Technological University, 21 Nanyang Link, Singapore, 637371, Singapore, Ruijie Zhang, Yuanguang Zhong

In this paper, we study a stochastic dynamic inventory scheduling problem faced by a capital-constrained company who periodically replenishes its inventory from a supplier. The problem is to determine the optimal inventory and financing decisions to maximize its expected terminal cash flow. Instead of assuming a certain demand distribution, we only require mean and variance of demand are known. We formulate this problem as a convex conic optimization problem which can be approximated using a positive semi-definite program. We study and compare two types of financing strategies: unsecured loans and asset-based loans.

#### 3 - Quantile Forecasting and Data-driven Inventory Management under Nonstationary Demand

Ying Cao, University of California, Berkeley, CA, 94720, United States, Max Shen, Max Shen

Most work in data-driven inventory management assume that historical demand can be regarded as samples drawn from a real distribution; or when demand distribution changes over time, multiple sample paths are available. In reality, however, demand is time-correlated and may exhibit nonstationarity. In this talk, we consider a general autoregressive demand process without prespecified parametric structure. Based on which, we present a neural network framework for predicting its quantiles, and argue that it is a data-driven approach for determining stock levels in the environment of newsvendor problem and its multiperiod extension. This is a joint work with Professor Max Shen from UC Berkeley.

#### 4 - Supply Chain Network Design and Coordination

Yun Zhang, Massachusetts Institute of Technology, Cambridge, MA, United States, David Simchi-Levi

We explore network design and coordination strategies in the context of modern supply chains, with a focus in public health.

#### ■ WB18

North Bldg 128A

#### Operations Management II

Contributed Session

Chair: Xinping Wang, College of Engineering, Nanjing Agricultural University, 40 Dianjiangtai Road, Nanjing, 210031, China

#### 1 - The Effect of Merger and Acquisition on Inventory Turnover

Zhihao Zhang, Student, University of South Carolina, Columbia, SC, United States

We evaluate the effect of merger and acquisition (M&A) on firms' inventory turnover, a well-developed measure of operations performance. By applying System Generalized Methods of Moments (GMM) and Discontinuous Growth Modeling (DGM), we are able to empirically test and show that mergers and acquisitions interrupt companies' inventory turnover in the short run, but eventually benefits companies in the long run. We also find that companies who face high demand uncertainty M&A benefits the most from the long-term synergies they created through M&A.

## 2 - Organizational Learning in Process Improvement Projects

Venkat Venkateswaran, Georgia Institute of Technology, Room 4143, 800 West Peachtree, NW, Atlanta, GA, 30308, United States  
Venkat Venkateswaran, University of Illinois, Urbana-Champaign, IL, United States, Edward Arnheiter

Many organizations engage in continuous process improvement activities. We study the learning that accrues when workers gain experience from such exercises. We use panel data from a large oil and natural gas extraction company to track the performance of 56 trained lean Six Sigma facilitators completing 233 projects over five years. The projects are all different, yet learning is discernible. Examples where trained personnel undertake activities not necessarily identical (the subject of traditional research) but falling within some discipline occur often in practice. For such applications, we propose a way to measure learning. The study data exhibits learning at an effective rate of about 85%.

## 3 - Optimal Decisions for Contract Farming under Weather Risk

Xinping Wang, Nanjing Agricultural University, Nanjing, China,  
Shengnan Sun

Agriculture has been greatly impacted by weather condition. In this paper, we consider a manufacturer who takes a farm crop as a raw material and transforms it into a finished product. The manufacturer encourages local farmers to grow the farm crop by offering them contracts to guarantee her supply under weather risk. Optimal decisions for two types of contracts, contract without reneging and contract with reneging, are analyzed. In addition, we numerically compare the optimal decisions of the company with different contracts and investigate the sensitivity of the results to the model parameters, such as weather condition.

## ■ WB19

North Bldg 128B

### Design of Two-sided Marketplaces

Sponsored: Revenue Management & Pricing  
Sponsored Session

Chair: Siddhartha Banerjee, Cornell University, Ithaca, NY, 14853, United States

Co-Chair: Pengyu Qian, Columbia University-Graduate School of Business, New York, NY, 10027, United States

Co-Chair: Yashodhan Kanoria, Columbia Business School, New York, NY, United States

### 1 - Simple Mechanisms for Two-sided Markets

Yang Cai, Yale University, New Haven, CT, United States

We design simple mechanisms to approximate the Gains from Trade (GFT) in two-sided markets with multiple unit-supply sellers and multiple unit-demand buyers. A classical impossibility result by Myerson and Satterthwaite showed that even with only one seller and one buyer, no Individually Rational (IR), Bayesian Incentive Compatible (BIC) and Budget-Balanced (BB) mechanism can achieve full GFT (trade whenever buyer's value is higher than the seller's cost). On the other hand, they proposed the "second-best mechanism that maximizes the GFT subject to IR, BIC and BB constraints, which is unfortunately rather complex for even the single-seller single-buyer case. Our mechanism is simple, IR, BIC and BB, and achieves 1/2 of the optimal GFT among all IR, BIC and BB mechanisms. Our result holds for arbitrary distributions of the buyers' and sellers' values and can accommodate any downward-closed feasibility constraints over the allocations.

### 2 - Descending Price Optimally Coordinates Search

Bo Waggoner, University of Pennsylvania, Philadelphia, PA, United States, Robert Kleinberg, Glen Weyl

Contrary to common practice in selling homes and start-ups, mechanism design theory typically recommends English (increasing price) over Dutch (decreasing price) auctions. Yet this theory neglects the uncertain investment required to investigate purchases. We show that English and other standard auctions burden such investments with further uncertainty about the price necessary to win, potentially eliminating all gains from trade. In contrast, Dutch auctions preserve their properties without information costs because they guarantee, at the moment when investigation is optimal, a price at which the good can be purchased.

### 3 - State Dependent Control of Closed Queueing Networks

Pengyu Qian, Columbia University-Graduate School of Business, New York, NY, 10027, United States, Siddhartha Banerjee, Yash Kanoria

We study the state dependent control for a closed queueing network model inspired by ridesharing systems. The platform can choose which supply unit to assign to an incoming customer; the unit becomes available again at customer's destination. The platform aims to minimize proportion of dropped demand. We propose a family of simple policies called Scaled MaxWeight (SMW) and prove that under complete resource pooling (analogous to Hall's condition), any SMW policy induces an exponential decay of demand-drop probability as the number of supply units goes to infinity. We further show that there is an SMW policy that

achieves the optimal exponent among all assignment policies and specify it analytically.

## 4 - Asymptotically Optimal Thickness of a Centralized Dynamic Matching Market with Independent and Identically Distributed Utilities

Lawrence M. Wein, Stanford University, Graduate School of Business, 655 Knight Way, Stanford, CA, 94305-5015, United States, Martin I. Reiman

We consider a centralized dynamic matching market, where buyers and sellers arrive according to independent Poisson processes with the same rate, and abandon (if not matched) after an exponential amount of time with the same mean. The matching utility between any buyer and seller is an iid random variable. Under a large-market asymptotic regime, we use extreme value theory and Markov chain asymptotics to show how the optimal market thickness varies according to the domain of attraction of the underlying matching utility distribution.

## ■ WB21

North Bldg 129B

### Revenue Management with Reusable Resources

Sponsored: Revenue Management & Pricing  
Sponsored Session

Chair: Cong Shi, University of Michigan, Ann Arbor, MI, 48105, United States

### 1 - Optimal Pricing Policy for Reusable Resource Systems with Strategic Customers

Yiwei Chen, University of Cincinnati, Cincinnati, OH, United States, Cong Shi

We consider a service system with a finite number of homogeneous reusable resources that dynamically serve customers. Customers stochastically arrive to the service system with heterogeneous requested service time intervals (allowing for advance reservations) and per unit of time service valuations. Customers are forward looking who strategize their purchase times. We propose a simple pricing policy that is fixed for each unit of time. This policy incentivizes customers to behave myopically. We show that this policy is asymptotically optimal.

### 2 - Real-time Dynamic Pricing for Revenue Management with Reusable Resources, Advance Reservation, and Deterministic Service Time Requirements

Yanzhe Lei, Queen's University, Kingston, ON, Canada, Stefanus Jasin

We study a dynamic pricing problem where a firm uses a finite amount of resources to serve price-sensitive customers arriving randomly over time. Each customer may request to consume a combination of different types of resources for a deterministic duration of time, after which the resource can be immediately used to serve new customers. We develop real-time pricing controls and show that they are near-optimal in the regime of large demand and large resource capacity. We further extend our result to a more general setting with heterogeneous service time and advance reservation.

### 3 - Reusable Revenue Management at Scale

Zachary Owen, David Simchi-Levi

We consider the problem of dynamic pricing and assortment optimization for reusable resource in continuous time under time-varying demand. We develop a time-discretization strategy that yields a constant factor performance guarantee relative to the optimal policy. Our policies are computationally feasible and asymptotically optimal for large systems. Additionally, we develop heuristic methods that implement a bid-price strategy that accounts for the changing value of resources over time.

### 4 - Dynamic Assortment Optimization for Reusable Products with Random Usage Durations

Mika Sumida, Cornell Tech, New York, NY, 10128, United States, Paat Rusmevichientong, Huseyin Topaloglu

We consider dynamic assortment problems with reusable products, in which each customer chooses a product within an offered assortment, uses the product for a random duration of time, and returns the product back to the firm to be used by other customers. The goal is to find a policy for deciding on the assortment to offer to each customer so that the total expected revenue over a finite selling horizon is maximized. We present a policy that is guaranteed to obtain at least 50% of the optimal total expected revenue. The policy is based on constructing linear approximations to the optimal value functions and is computed through an efficient backward recursion.

## ■ WB22

North Bldg 130

**Practice – Finance – Risk Management**

Contributed Session

Chair: Tiantian Lin, Zhejiang University, Zhejiang Sheng, China

**1 - Effect of Venture Capitalist Competition on Seed Funding for Supply Chains**Joyaditya Laik, PhD Candidate, University of Pittsburgh,  
241 Mervis Hall, Katz Business School, Pittsburgh, PA, 15260,  
United States

Startup's raise capital by various means. One of them is by appealing to a Venture Capitalist whose primary stake in the form is the equity he owns. We model a situation when there are two 'types' of VCs and study the effect on the equity shared when both VCs are present. We observe that the equity that's given out is smaller with competition as compared to when there is no competition and that the equity demanded increases in the uncertainty of the potential market demand.

**2 - Cooperative Resolution of Crises in Financial Networks**Markku Kallio, Professor, Aalto University School of Business,  
Pohjoiskaari 17 D. 17, Helsinki, FIN-00200, Finland,  
Aein Khabazian

We examine the financial network of systemically important banks as a cooperative game. Governments can act as facilitators enforcing incentives for banks to cooperate and prevent the escalation of a financial crisis. To achieve fair allocation of bailout costs, we use nucleolus which implies a possible subsidizing pattern among the banks. Our approach helps avoid moral hazard and free rider problems. For a demonstration, we use major European banks and a scenario which is linked to the adverse economic scenario used in 2016 EU-wide stress testing. Rescue performance is compared with several alternative non-cooperative approaches.

**3 - A Linear Omega Portfolio Model with Optimizing Return Threshold**Jing-Rung Yu, Professor, National Chi Nan University,  
470 University Road, Puli, Nantou, 545, Taiwan, Paul Chiou,  
WenYi Lee

The omega ratio incorporates both the upside profit and downside risk with considering a return threshold. Although the threshold can affect the effectiveness of the Omega portfolio model, its determination has not been thoroughly studied yet. A conventional fixed-value approach simplifies investor's decision without taking economic dynamics into account. This study optimizes the threshold value in the Omega model under certain and uncertain return distributions. The empirical results using the daily returns of the S&P 500 Index composite stocks show that the proposed WOmega model yields lower loss values and better controlling the downside risk than the CVaR related counterparts.

**4 - Pass-through of Commodity Price Shocks in Distribution Channels with Risk-averse Agents**Phat Luong, Rutgers University, Piscataway, NJ, United States,  
Xiaowei Xu

This paper studies how to allocate risk in distribution channels, in which a risk averse supplier faces commodity price shocks and a risk averse buyer faces downstream market uncertainty. The supplier can pass-through commodity price shocks to the buyer under a surcharge pricing system, which is widely used in the steel industry. We model the buyer-supplier relationship as either a Stackelberg leadership game or a Nash bargaining solution. By conducting variance analysis on commodity price shocks and market uncertainty, we derive the closed-form optimal pass-through rate of commodity price shocks, which minimizes the weighted total channel risk and maximizes the channel throughput.

**5 - The Allocation of Financial Risk in a Supply Chain with Influence of Supply Chain Characteristics**Tiantian Lin, Zhejiang University, Hangzhou, China, Gangshu Cai,  
Weihua Zhou

Buyer financing from e-commerce platform and trade credit are two popular financing methods for e-commerce SMEs. The two represent different ways of risk allocation. To detect which kind of risk allocation is more efficient, and how supply chain features influence, we construct a supply chain with a retailer, a manufacturer and a distributor on a consignment basis. We find neither buyer financing nor trade credit always outperforms the other. And the supply chain features like leadership structure influences not only the efficiency of the same risk allocation, but also relative efficiency of different risk allocation.

## ■ WB23

North Bldg 131A

**Financial Engineering Topic**

Sponsored: Finance

Sponsored Session

Chair: Xuedong He, The Chinese University of Hong Kong, Shatin, Hong Kong

Co-Chair: Nan Chen, Chinese University of Hong Kong, Shatin N. T, Hong Kong

**1 - Profitability of Electronic Market Making and Latency**Xuefeng Gao, Chinese University of Hong Kong, William M.W.  
Mong Engineering Building, Room 606, Shatin, Hong Kong

This paper studies the profitability of electronic market making strategies and the impact of latency on market makers' profits for large-tick assets. By analyzing the optimal market making problem using Markov Decision Processes, we provide simple conditions to identify when market making strategy is profitable. We also show that higher latency leads to reduced profits for market makers. Numerical experiments are conducted to illustrate the impact of latency and relative latency on the profitability of market making strategies. This is a joint work with Yunhan Wang.

**2 - Addressing Systemic Risk Using Contingent Convertible Debt – A Network Analysis**Yueliang Lu, UNC Charlotte, Charlotte, NC, United States,  
Aparna Gupta, Runzu Wang

We construct a balance sheet based network model to study the interconnectedness of US banking system. After a simulation analysis of the buffer effect of contingent convertible (CoCo) debt in controlling contagion in the banking network under a theoretically motivated model, we use 13-F filings made to the US Securities and Exchange Commission (SEC) to calibrate the theoretical model. Our results demonstrate that CoCo debt conversion significantly reduces the average number of bank failures, decreases the CoVaR of the banking system, and thus, mitigates systemic risk. While CoCo debt with dual-trigger is not so efficient as a single trigger design in reducing individual bank failures, the former is more effective at protecting the surviving banks, which leads to improved stability from the perspective of the banking system. We claim that the different designs of CoCo triggers result in trade-offs for addressing systemic risk, which may be evaluated in a network model developed in this work.

**3 - Portfolio Selection under Loss Aversion with a Mentally Adjusted Reference Point**Moris Strub, The Chinese University of Hong Kong, Shatin,  
Hong Kong, Xuedong He

Most models on portfolio selection under loss aversion make a strong assumption on what the reference point is or how it is formed. In this paper, we relax this assumption by proposing three models where the investor mentally adjusts an initial, exogenous reference point: A model of mental reference point updating, a model of a partially endogenous reference point and a model of a mentally optimal reference point. We find that optimal trading behavior is remarkably robust with respect to mental reference point formation and converges to the neoclassical prediction with increasing experience and sophistication of the investor.

**4 - Dynamic Mean-risk Asset Allocation**Xuedong He, The Chinese University of Hong Kong, Room 609  
William M.W. Mong Engineering Bldg, Shatin, Hong Kong,  
Zhaoli Jiang

In a market that consists of multiple stocks and one risk-free asset whose expected return rates and volatility are deterministic, we study a continuous-time mean-risk portfolio selection problem in which an agent is subject to a constraint that the expectation of her terminal wealth must exceed a target and minimizes the risk of her investment, which can be the variance or tail risk of her terminal wealth. Considering three types of expected terminal wealth target, we derive the equilibrium policy in closed form, and this policy is myopic and does not depend on the risk measure used by the agent nor on the agent's evaluation period.



## ■ WB24

North Bldg 131B

### Finance - Theory & Empirics

Contributed Session

Chair: Peng Xie, California State University, Hayward, CA, 94542, United States

#### 1 - Politics and Inventory: Chief Executive Officer – White House Political Ideology Alignment and Inventory Management

Mazhar Arikan, University of Kansas, Lawrence, KS, 66045, United States, Yi Tan, Yaoyi Xi

We empirically examine whether and how CEO political ideology affects inventory strategies. Using a sample of 3,461 distinct U.S. domestic publicly traded firms, we find that firms tend to hold more inventories during the periods when their CEOs' personal political ideology (measured by donations to political parties) is in accordance with the President of the U.S. We perform further analyses on firm financial performance and economic policy uncertainty to investigate the underlying mechanisms for this finding. Results indicate that CEO-President political ideology alignment does not provide an information channel through which CEOs can exploit additional value-related information.

#### 2 - Distance-based Portfolio Combining Algorithm to Predict in Sample Optimal Portfolio

Hongseon Kim, Yonsei University, ShinChonDong, Daewoo Hall 610, Seoul, Korea, Republic of

We provide portfolio combination algorithms for reducing Euclidean distance between in-sample portfolio and out-of-sample portfolio. These algorithms combine various out-of-sample portfolio depending on the length of the Euclidean distance and tracking signal. We conducted an empirical experiment using 21 data sets. We find that combined portfolio which we propose often has a short Euclidean norm and higher Sharpe ratio than other benchmark portfolios.

#### 3 - The Effect of Initial Coin Offering Uniqueness on its Valuation and Trading Status

Peng Xie, Assistant Professor, California State University, Hayward, CA, 94542, United States

As the development of the cryptocurrency ecosystem, a new way to raise funds for new cryptocurrency ventures called Initial Coin Offering (ICO) becomes popular. Using data from more than 1,000 ICO campaigns from 2017 to 2018, we empirically show that the uniqueness of the ICO ideas is positively correlated with the cumulative returns and the probability of ongoing trading in cryptocurrency exchanges.

## ■ WB25

North Bldg 131C

### Service Sharing

Sponsored: Service Science

Sponsored Session

Chair: Anita D. Bhappu, University of California-Merced, Merced, CA, 95343, United States

#### 1 - Bonus Scheme Design in Ride-sharing Economy under Competition

Puping Jiang, PhD, Washington University in St. Louis, Olin Business School, Campus Box 1156, St. Louis, MO, 63130-4899, United States, Fuqiang Zhang, Kaitlin Daniels

Nowadays in the ride-sharing economy, one phenomenon takes our attention is the platform's "convex"-like bonus policy towards drivers. In this research we mainly address two questions: First, what is the main driving force behind such bonus schemes? Second, why does the bonus scheme have the "convex"-like form? This is the first research in ride-sharing economy as far as we know looking at the competition between two ride-sharing platforms.

#### 2 - What Types of Drivers Do Our Society Need? The Effect of Drivers' Refusing Behavior

Xiaojing Feng, Shanghai Jiao Tong University, Minneapolis, MN, 55454, United States, Ying Rong, Tony H. Cui

Although the empirical evidence shows that the driver's strategic refusing behavior is one of the key factors that contribute to high incomes, it harms the feelings of the refused passengers, which may cause passengers' complaints. We propose an analytical model to capture the refusing behavior of different types of drivers, depict the game dynamics between drivers, and try to explore the effect of the refusing behavior on the social welfare under different regulations.

#### 3 - Social Determinants of Health Information Technology Enabled Patient Provider Engagement among Patients with Multimorbidity

Ajit Appari, Worcester Polytechnic Institute, Worcester, MA, 77030, United States, Meghan Hufstader-Gabriel

Our understanding of health information technology (IT) enabled patient-provider engagement by patients with multimorbidity is limited despite growing trends of health IT diffusion. We analyzed 2017-Health Information National Trends Survey data on American adults (18+ yrs old) using weighted ordered logistic regression to evaluate association of health IT enabled engagement (Low, moderate, High) with demographic and socioeconomic factors for Low (2-3 conditions) and High (4+ conditions) multimorbidity groups separately. Our study did not find association of health IT enabled engagement with any covariate, except older patients more likely to engage.

#### 4 - Online Demand Driven Car Sharing Rebalancing

Xiaopeng Li, Dr., University of South Florida, Tampa, FL, 33620, United States, Dongfang Zhao

This study proposes an online car-sharing rebalancing model to deal with the car sharing fleet management problem using reinforcement learning. We develop a multi-agent reinforcement learning framework using a deep Q-learning algorithm. The goal of the algorithm is to maximize the total profit of the platform by repositioning available cars to the locations with outstanding demand-supply gaps. This model does not make any assumption on the demand and is completely driven by spatially distributed demand data history. We show significant improvements of the proposed framework over state-of-the-art approaches through extensive empirical studies.

#### 5 - Service Delivery in the Sharing Economy: Platform Assumptions and Technology Affordances for Prosumer Service Interactions

Anita D. Bhappu, University of California Merced, 5200 N. Lake Road, SSM 233, Merced, CA, 95343, United States, Melanie Lisa Yeo, Ann Kovalchick, Tea Lempiala

We develop a framework for understanding the nature of service delivery in the sharing economy by applying the literature on service science to three exemplar ridesharing platforms. To facilitate and support our analysis, we critically examine and discuss these platforms' implicit assumptions about service interactions and prosumer motivations as evidenced by their designed technology features. We also assess these platforms' technology affordances for service governance and prosumer trust.

## ■ WB26

North Bldg 132A

### Stochastic Models for Service Operations

Sponsored: Service Science

Sponsored Session

Chair: Xu Sun, Columbia University, New York City, NY, 10027, United States

#### 1 - Extremal Single-Server Queues Given Two Moments

Yan Chen, Columbia University, New York, NY, 10027, United States, Ward Whitt

This paper establishes tight upper bounds for the mean steady-state and transient waiting times in the GI/GI/1 queue given the first two moments of the inter-arrival times and service-time distributions. We apply the theory for the classical moment problem to show, for distributions with support on bounded intervals, that the bounds are attained at distributions with support on at most three points. For distributions with support on the unbounded positive real line, we show that the bounds are not attained directly, but are obtained asymptotically. We propose a simple approximation formula and provide a numerical comparison of the approximations and bounds.

#### 2 - Optimal Charging Control in an Electric Vehicle Battery Swap Station

Xu Sun, Columbia University, New York City, NY, 10027, United States, Bo Sun, Ward Whitt

We model an electric vehicle battery swap station as a closed-loop production-inventory system facing time-varying demand for battery swap and time-varying prices for recharging batteries. The objective is to find an optimal charging policy that best trade off the charging cost and the congestion. We first formulate a Markov decision process (MDO) and then develop a fluid model approximation for the (MDP). We gain important managerial insights by solving the fluid model optimization.

### 3 - To Pool or Not to Pool: Queueing Design for Large-scale Service Systems

Yunan Liu, North Carolina State University, Raleigh, NC, 27695-7906, United States, Ping Cao, Shuangchi He, Junfei Huang

Two queue structures are commonly adopted in service systems: pooled and dedicated. Although the pooled structure, known to minimize server idleness, is widely used in service systems, this study reveals that the dedicated structure, along with the join-the-shortest-queue policy, could help improve certain service levels such as the probability that waiting time is less than a delay target. Using a fluid model substantiated by asymptotic analysis, we provide performance comparison of the two structures in a queueing system with customer abandonment. We intend to answer the questions: To achieve a specified service level, which structure will be more cost-effective? How many servers can be saved?

### 4 - Asymptotically Optimal Priority Allocation for Transplant Queueing Systems

Xin Liu, Clemson University, Department of Mathematical Sciences, Clemson, SC, 29634, United States, Amin Khademi

We study the allocation problem for organ transplant systems. The system is formulated as a two-sided multi-class matching system, in which patients may change classes, or abandon the system. We develop a simple priority policy, and show that the proposed policy is asymptotically optimal under fluid scaling.

## ■ WB27

North Bldg 132B

### Practice- Information Systems I

Contributed Session

Chair: Jiaying Deng, University of Washington, 4109 Stevens Way, Seattle, WA, 98195, United States

#### 1 - Understanding Post-adoption of Building Information Modeling in Organizations: A Behavior Perspective

Pei Ma, Tianjin University, Building 25, Weijin Road, Tianjin, 300072, China

Post-adoption is crucial for organizations to realize returns on BIM investment. However, employees rarely use BIM to its fullest potential. We identify exploitation (EI) and exploration (ER), that refer to using BIM in routine way or novel way separately, as two types of usage behaviors. Based on IS continuance model, we examine the impacts of satisfaction (SAT) and perceived usefulness (PU) on ER and EI, and the role of personal innovativeness with IT (PIIT) and organizational support (OS) as moderators. Empirical analysis indicates (1) SAT impacts ER and EI strongly, (2) PU has stronger impact on EI than ER, (3) PIIT positively moderates impacts on ER, (4) OS positively moderates impacts on EI and ER.

#### 2 - Social Responsibility Platforms and Sustainability Reporting

Xue Ning, Business School, University of Colorado, Denver, CO, 80202, United States, Dobin Yim, Jiban Khuntia

This study suggests and investigates the effect of a governance-practice-performance path for social responsibility platforms. Using a dataset of annual sustainability reports of 683 firms over a three-year period, findings of analysis provide insights to implement and steer sustainability governance to better performance.

#### 3 - How Different Incentives Influence Employee Behavior on Enterprise Social Media

Xiaopeng Luo, Beijing University of Posts and Telecommunications, 10 Xitucheng Road, Beijing, 100876, China, Jiayin Qi, Xiangling Fu, Yu Jeffrey Hu

Firms are currently eager to apply ESM (Enterprise Social Media) to facilitate internal information sharing. However, employee engagement on ESM decreases over time. Thus, incentives are widely used to motivate participation. In this paper, two different incentives adopted on ESM have been examined in the context of a large state-owned company. By conducting a quasi-experiment based on the data of 11,432 employees, this study indicates the effect of the two incentives are different: group incentives, which reflect a sense of collectivism, are welcomed to strengthen the social relationships. While individual incentives, which show a spirit of egoism, can be harmful to evoke participation.

#### 4 - Can Employees Benefit from Social Capital?

The Evidence from an Enterprise Social Media in China

Jiaying Deng, University of Washington, Seattle, WA, 98195, United States, Yong Tan

In this study, we focus on how employees use the ESM to communicate with each other, and how this communication will affect their collaborative project performance. There's a trade-off. On the one hand, employees may acquire knowledge from others through communication, both from project team members or other experts outside the team. On the other hand, the convenience

of chat may result in too many communications, which may distract employees from projects they are working on. In this paper, we try to examine these two effects. Our preliminary result shows that with more and more communication, the project performance significantly decreases over time.

## ■ WB28

North Bldg 221A

### Practice – Logistics II

Contributed Session

Chair: Srimathy Mohan, Arizona State University, Department of Supply Chain Management, W.P. Carey School of Management, Phoenix, AZ, 85069-7100, United States

#### 1 - Locating a Biorefinery under Uncertainty Using a Multistage Scenario Tree

Javier Faulin, Public University of Navarra, Campus Arrosadia, Department of Statistics and OR, Pamplona, Navarra, 31006, Spain, Adrian Serrano-Hernandez, Luis Cadarso, Alejandro Garcia del Valle

This work introduces a case study in which a biorefinery has to be located in Navarre, Spain, considering uncertainty in prices and biomass availabilities. To address this problem, stochastic optimization is employed. A multistage scenario tree featuring strategic and operational scenarios is presented, where operational nodes are rooted in strategic nodes. Then, biorefinery location optimization is reached by solving a mixed integer linear programming model. Promising results are obtained at strategic (location of the facility), tactical (location of collection points), and operational (biomass purchase management) levels.

#### 2 - Sharing Loading Costs for Multi Compartment Vehicles

Bruce C. Hartman, Professor, California State University Maritime, Santa Rosa, CA, 95409, United States

Cold chains are important in world trade. Loading cold items into multiple compartment vehicles (MCVs) with different temperature compartments can keep goods at proper temperatures, allowing better load consolidation. Constructing the optimal load requires heuristics, and the cost must be allocated in a stable manner to the items being shipped. We outline the MCV loading problem, and suggest the optimization and cost allocation problems be solved together using an inductive approach. Constraints generated inductively from minimal balanced collections of subsets reduce the feasible set, helping heuristics find a stable result faster than optimizing first and allocating later.

#### 3 - Long Term Sorting Plan Model for Ecommerce Logistic Distribution Network

Jie Lu, Operations Research Scientist, JD.com, Beijing, China, Hengle Qin

A sorting plan organizes the package flows in the distribution network. It determines package flow combinations and the sequence of distribution centers for each origin-destination pair. In this study, we propose an optimal long-term sorting plan model for a distribution network. In particular, a mixed integer programming model with conditional constraints is developed. We derive a reformulation of the problem to handle the conditional constraints using logical equivalence. The results show that the model can handle hundreds of distribution centers and more than six thousands of routes.

#### 4 - A Beam Search Based Method for Single Container Mix Loading Problem

Tian Tian, Associate Professor, Dongbei University of Finance and Economics, Shahekou District, 217 Jianshan Street, Dalian, China, Jiafu Tang

An audio equipment manufacturer would like to depalletize PSUs and load the individual products, together with other PSUs, into a container, such that the volume utilization of the container is maximized. Once a PSU is depalletized, all of its products must be loaded into the Container. No PSU should be depalletized if the total volume of complete PSUs loaded in the container is not maximized. This problem is named as Single Container Mix-Loading Problem (SCMLP). We prove that SCMLP is a generalized container loading problem. We develop a beam search based two-phase constructive algorithm. We generated 60 test instances and conducted experiments to demonstrate the effectiveness of our approach.

#### 5 - Realizing Business Potentials from Digital Operations in a Smart Port. A Quantitative View on Container Terminal Operations

Leif Meier, University of Applied Sciences Bremerhaven, An der Karlstadt 8, Bremerhaven, 27568, Germany

Business Managers need to evaluate the impact and potentials from new technologies to change the current situation at any time, i.e. to decrease costs, to increase sales and/or increasing the process flexibility. Therefore, new smart procedures do not require a new thinking in management; they are just another technology that may influence the current business situation. Quant Methods allow unfolding potentials that arise from data-driven-technologies - if we understand and solve the right problems. This study shows potentials - and also limits - from smart Container Terminal operations.

## 6 - Impact of Facility Location and Inventory Allocation in a Blood Supply Chain

Srimathy Mohan, Arizona State University, Department of Supply Chain Management, W.P. Carey School Of Management, Tempe, AZ, 85287-4706, United States, Mohan Gopalakrishnan

The blood supply chain must be well coordinated and high performing. Using American Red Cross (ARC) data, this research focuses on analyzing the strategic decisions that are made when planning for non-blood inventories including, facility location and resource allocation decisions. We first formulate a fixed-charge model to minimize the total cost locating the non-blood supplies and transporting them to the demand points when required. We will also conduct sensitivity analyses for demand input and the fixed facility cost and analyze the impact on location and size decisions. We thus contribute to “management engineering” in the humanitarian logistics domain.

## ■ WB29

North Bldg 221B

### Ride Sharing and Microtransit

Sponsored: TSL/Urban Transportation

Sponsored Session

Chair: Changhyun Kwon, University of South Florida, Tampa, FL, 33620, United States

#### 1 - Locality Sensitive Hashing Based Matching for Ride-Sharing

Chinmoy Dutta, Lyft, Mountain View, CA, 94040, United States

A standard approach to ride-matching is to generate all feasible matchings of rides, filter and score them, and solve a constraint optimization problem. For large ride-sharing platforms, generating all the feasible matchings is an impractical combinatorial problem. We propose a novel method to circumvent this combinatorial challenge using locality-sensitive hashing which lets us efficiently construct a high-quality set of feasible matches.

#### 2 - A Practical Iterative Combinatorial Auction Design for Fractional Ownership of Autonomous Vehicles

Aigerim Bogrybayeva, University of South Florida, Tampa, FL, United States, Mahdi Takaloo, Hadi Charkhgard, Changhyun Kwon

This study explores a market design for fractional ownership of autonomous vehicles (AVs), where an AV is co-owned by a group of individuals. In particular, a practical combinatorial auction design based on the well-known Combinatorial Clock Auction is proposed. The study discusses the unique features and challenges of the proposed auction and provides insights on the design performance based on numerical experiments.

#### 3 - Computationally Efficient Truthful Mechanisms for Large-scale P2P Ridesharing Systems

Neda Masoud, University of Michigan Ann Arbor, 2350 Hayward St., 2124 Gg Brown Bldg., Civil And Environmental Engineering, Ann Arbor, MI, 48109, United States, Roger Lloret

We present a truthful Maximal-In-Distributional-Range (MIDR) randomized mechanism for NP-hard large-scale P2P ride-sharing problems, based on the Lavi-Swamy scaling decomposition technique. Instead of using the ellipsoid algorithm, we design a column generation scheme which makes the technique tractable for large-scale problems. Two pricing problems are tested: exponential exact and quasi-polynomial state-space relaxation.

## ■ WB30

North Bldg 221C

### Advances in Facility Location Algorithms

Sponsored: TSL/Facility Logistics

Sponsored Session

Chair: Xin Wang, University of Wisconsin-Madison, Madison, WI, 53562-4278, United States

#### 1 - Linear-Time Sweeping Algorithm for Discretization of Continuum Approximation

Xiaopeng Li, University of South Florida, Tampa, FL, 33620, United States, Hongqiang Fan, Lifan Yun

This paper proposes a construct-heuristic algorithm, the direct sweeping algorithm, to discretize a continuous location solution for the continuum approximation model. This algorithm is based on the idea of spatial searching and has only a linear computational complexity. Through the numerical examples, we study the performance of our proposed algorithm. The results of case studies indicate that this algorithm can solve the discrete facility locations problem more efficiently and has a robust performance compared with existing discretization algorithm.

#### 2 - Charging Electric Vehicle Sharing Fleet

Long He, National University of Singapore, Mochtar Riady Building, BIZ1 8-73, 15 Kent Ridge Drive, Singapore, 119245, Singapore, Guangrui Ma, Wei Qi, Xin Wang

In this paper, we develop models to jointly optimize the sites and sizes of charging stations, along with the coupled fleet charging and repositioning operations. We closely track EV energy levels and explicitly depict stochastic charging operations. We formulate the problem as a nonlinear optimization program and develop approximation optimization models as lower and upper bounds, which is computationally efficient. With real data sets of car2go's operations in San Diego, we further conduct retrospective and futuristic case studies to discuss several managerial implications.

#### 3 - Integrating Car-sharing with Public Transit

Xin Wang, University of Wisconsin-Madison, Madison, WI, 53562-4278, United States, Yikang Hua

Car sharing service complements public transit with flexibility while reducing personal vehicles ownership. We build a continuous approximation model to help design car sharing infrastructure based on existing public transit network. We consider both the profitability of car sharing service and improvement of travelers' utility.

#### 4 - Performance Evaluation and Optimization of Reliable Sensor Deployment

Zhoutong Jiang, University of Illinois, Champaign, IL, 61820, United States, Siyang Xie, Yanfeng Ouyang

The accuracy of object positioning and surveillance depends on how multiple sensors are deployed in the sensor system and might suffer from probabilistic disruptions. To evaluate the performance of such system and optimize the sensor deployment strategy under different design criteria, we first develop a continuum approximation model to estimate the system cost and then optimize the sensor deployment strategies for different objectives. A series of numerical experiments are conducted to illustrate how the proposed model can be applied to provide near-optimum results within a very short computation time.

## ■ WB31

North Bldg 222A

### Transportation-Planning II

Contributed Session

Chair: Zhongxiang Wang, University of Maryland, Greenbelt, MD, 20770, United States

#### 1 - A Hub-based Rebalancing Method for Free-floating Bike Sharing Systems

Vahid Mahmoodian, PhD Student, University of South Florida, ENG 226, 4202 E. Fowler Ave, Tampa, FL, 33620, United States, Yu Zhang, Hadi Charkhgard

In this study, a hub-based simulation model is presented to rebalance bikes in a free-floating bike sharing system. Such systems are one of the new transportation modes that received attention in recent years. This is highlighted by the fact that many companies with station based bike sharing systems are switching to free-floating systems. The proposed model takes advantage of both user and operator based rebalancing in order to maximize the service level and minimize the cost. The approach is applied to a real-world bike sharing setting and computational results show its efficacy.

#### 2 - Taxonomy and Abstraction of the On-demand Mobility Aviation System for Smarter Cities

Wancheng Dai, Florida Institute of Technology, 150 W. University Blvd, Melbourne, FL, 32901, United States, Rodrigo Mesa Arango

On-demand mobility (ODM) is a new transportation system providing point-to-point air services to metropolitan travelers. ODM can significantly decrease travel times and potentially improve several ground-transportation externalities, like emissions and congestion. However, the complexity and novelty of future ODM systems impede its proper understanding for informed decisions. This work employs a system of systems framework to characterize the ODM system, and guide modeling efforts that can answer related questions by stakeholders of the system.

#### 3 - A Cell-based Transportation Planning Model of Humanitarian Logistics and its Application

Kazuaki Okubo, Associate Professor, Ehime University, 3 Bunkyo machi, Matsuyama city, Matsuyama, 790-8577, Japan, Pang-jo Chun

We proposed an optimal transportation model for emergency relief supplies based on cell-based Merchant Nemhauser model. The model minimizes the total transportation time from supply origins to shelters and provides an optimal allocation of the supplies and labors in a dynamic setting. We applied the model to an earthquake disaster in Ehime Prefecture to evaluate the effect of changes in depot location. We show an additional depot enables the transportation in the shorter time. And it also improves the robustness of transportation against variation in the amount of supply and demand.



#### 4 - A Design of a Socially Inclusive Bikeshare System with Station Location Optimization

Xiaodong Qian, University of California-Davis, Davis, CA, 95616, United States, Miguel A.Jaller Martelo

Bikeshare programs are increasingly popular in the United States. However, far less attention has been paid to bikeshare programs' potential to provide greater essential services for underserved communities. To date, there is virtually no quantitative research on how to design bikeshare systems for underserved communities. This research is aimed at designing a socially inclusive bikeshare system from the perspective of bikeshare station optimization. We will decide the optimized locations by solving a multi-objective optimization problem: 1) minimizing the differences of accessibility improvement between different communities and 2) maximizing the revenue generated.

#### 5 - Estimating the Influence of Time Perception in Mode Choice for a Gondola Lift Transit System – Metrocable Medellin

Daniela Jurado, Universidad Nacional De Colombia Sede Medellin, Carrera 78AA#56-49, Medellin, 050034, Colombia, Rodrigo Mesa Arango

This research studies the effect of access-queue time on the choice between competing transit modes, i.e., bus and Metrocable (an unconventional gondola lift transit system), in Medellin, Colombia. Data from Metrocable's critical influence areas are collected through stated/revealed preference surveys. Advanced econometric models are used to quantify the effect of queue waiting time perception on mode choice. Results support the implementation of policies to reduce queue-time subjectivities and increase system demand.

#### 6 - A Fast Heuristic Algorithm for School Bus Routing Problems with Trip Compatibility

Zhongxiang Wang, PhD Candidate, University of Maryland, Greenbelt, MD, 20770, United States, Ali Shafahi, Ali Haghani

School bus planning problem is decomposed into the routing and scheduling subproblems. We present a new approach to incorporate the scheduling information (trip compatibility) into the routing such that the interrelationship between subproblems is considered in the decomposed problems. A novel heuristic is presented to solve the decomposed school bus routing problem with the trip compatibility. The first step finds an initial solution using an iterative minimum cost matching-based insertion heuristic. Then, the initial trips are improved using a Simulated Annealing and Tabu Search hybrid method. Experiments show our heuristic improves existing solutions up to 25% on the benchmark problems.

### ■ WB32

North Bldg 222B

#### Practice- Vehicle Routing II

Contributed Session

Chair: Darweesh E. Salamah, Mississippi State University, MS, 39763-9542, United States

#### 1 - The Model and Optimization of Container Drayage Problem in Truck Platooning Mode

Jintao You, PhD Candidate, Graduate School at Shenzhen, Tsinghua University, E302F, Datong building, University Town, Shenzhen, 518055, China, Zhaojie Xue

This paper investigates a container drayage problem in which trucks operate in platoon mode. One fleet can be operated by only one driver in the leading truck, while the rest trucks follow the leading one by using semi-autonomous driving technique. A group of leading manned trucks and following unmanned trucks are synchronously scheduled to serve a set of full-container-load customers within a time horizon. A general mathematical model is proposed to describe this problem as a variant of VRP with alterable capacity, temporal constraints and OD pairs. Considering the NP essence of this problem, a local search based heuristic method is proposed to solve the problem.

#### 2 - An Optimized Route for Q100's Bert and Kristin to Visit All Jersey Mike's Subs in Atlanta for Charity

Jessica Rudd, PhD Student, Kennesaw State University, 1000 Chastain Rd, Kennesaw, GA, 30144, United States, Lauren Staples, Sanjoosh Akkineni, Andrew Henshaw

The project built an optimal route for two popular radio show hosts to visit each of the 37 Atlanta area Jersey Mike's Subs in one day. This supported a fundraising effort to send children with chronic and terminal illnesses to Disney World. We developed a combined approach to the Multiple Traveling Salesman Problem that pairs a custom genetic algorithm with Google's combinatorial optimization solver.

#### 3 - Work Crew Routing Problem for Infrastructure Network Restoration

Nazanin Morshedlou, University of Oklahoma, Norman, OK, 73071, United States, Kash Barker, Andres David Gonzalez

This presentation introduces a synchronized routing problem for planning and scheduling restorative efforts for infrastructure networks in the aftermath of a

disruptive event. In this problem, a set of restoration crews are dispatched from depots to a road network to restore the disrupted infrastructure network. Two mathematical formulations are presented to scheduling and sequencing disrupted network components to restoration crews and route the crews towards disrupted components to maximize network resilience progress in any given time horizon. We further introduce a feasibility algorithm to derive a strong initial solution for the routing restorative capacity problem.

#### 4 - Management of Charging Stations' Interrelated Electrical Infrastructure Systems under Major Disruption:

##### A Mathematical Model

Darweesh E. Salamah, Mississippi State University, Mississippi State, MS, 39762, United States, Mohannad Kabli, Mohammad Marufuzzaman, Salem Batiyah

Electric vehicles are envisioned to become the main transportation mode for the future. Electrical Infrastructure is a vital component in the operation of electric vehicles' charging stations. Building a resilient electric system that minimizes the power restoration time is essential for a smooth operation of future transportation modes. This paper aims to fortify the connections within and in between all related electrical structures and charging stations to face against any deliberate or sudden power disruptions. A mathematical model is built with the aim of minimizing disruption costs.

### ■ WB33

North Bldg 222C

#### Vehicle Routing

Contributed Session

Chair: Jihyun Jo, Pennsylvania State University, 234 Leonhard Building, University Park, PA, 16802, United States

#### 1 - Routing Optimization in Bulk Transportation with Compatibility Constraints

Ugandhar Delli, Graduate Research Assistant, Kansas State University, Manhattan, KS, 66502, United States, Ashesh Kumar Sinha

We analyze bulk transportation with specialized wash operation after every delivery. Unlike traditional vehicle routing problems, the interaction properties of chemical/liquid bulk orders must also be accounted for that impose complex product-sequencing constraints. We propose an integrated approach that combines the efficacy of column generation and efficient graph decomposition to account for compatibility constraints while optimizing trailer-wash-order combinations.

#### 2 - A Risk Based Border Surveillance Using Drones with a Dynamic Wireless Charging System

Navid Ahmadian, University of Houston, Houston, TX, United States, Gino J. Lim, Seon Jin Kim, Maryam Torabbeigi

We propose a risk-based surveillance model using unmanned aerial vehicles (UAVs) for border patrol. The short flight duration of drones is a major drawback for such a system. So, we use the dynamic wireless charging system to increase the flight time of the drones in real time. Assuming that each location is associated with a different priority of coverage, a risk-based MIP model is proposed to increase the frequency of visiting the highly critical locations. To accomplish our goal, we first split the total area into sub-areas based on the risk associated with their location, and assign a drone to each sub-area. Then, we find the optimal path and also location of the E-line system related to each drone.

#### 3 - Asymmetric Formulations for the Symmetric Capacitated Vehicle Routing Problem

Sune Lauth Gadegaard, Assistant Professor, Aarhus University, Fuglesangs Alle 4, Aarhus V, 8210, Denmark, Jens Lysgaard

In this talk, we present results obtained using new polynomial formulations for the symmetric capacitated vehicle routing problem. The formulations decompose each route into two paths originating at the depot and meeting at the customer having the largest index (the peak customer) on the route. We outline a branch and bound like algorithm exploiting the formulation and present computational results.

#### 4 - Multi Objective Models for Dynamic Vehicle Routing Problem in City Logistics

Gitae Kim, Hanbat National University, Dept. of Industrial Management Engineering, School of Engineering, Daejeon, 34158, Korea, Republic of

Stakeholders such as shippers, carriers, residents, and local authorities in city logistics have their own different objectives that may cause conflicts each other. Accordingly, the city vehicle routing problem could consider the benefits of stakeholders. However, there are lack of studies considering the concerns of multiple stakeholders. This paper investigates the multi objective models for the vehicle routing problems in city. We consider both dynamic and stochastic conditions for the vehicle routing problem. The stochastic dynamic programming model combined with multi objective model is proposed. We also provide the numerical results to present the models.

### 5 - The Time Dependent Vehicle Routing Problem with Time Windows and Real Traffic Penalties Benchmark Problems and a Simulated Annealing Heuristic

Shin-Yu Lin, Metropia, Tucson, AZ, 85719, United States  
National Taiwan University of Science and Technology, 43,  
Section 4, Keelung Road, Taipei, 10607, Taiwan, Yi-Chang Chiu,  
Vincent F. Yu, Ali Arian

In this study, the time dependent vehicle routing problem with time windows and real traffic penalties (TDVRPTW-RTP), a variant of vehicle routing problem (VRP) when considering time dependent travel times, time windows demands, and traffic behavior, is introduced and formulated. A new dataset is created by modifying Solomon dataset and is solved by our proposed simulated annealing heuristic (SA) and multi-start SA (MSA). This study collects time dependent travel time with traffic penalties data and apply our proposed heuristic to a real world application in Taipei, Taiwan. The best solutions during the sensitivity analysis are used as benchmarks for further research comparing.

### 6 - Vehicle Routing Problem with Markov Decision Process

Jihyun Jo, Pennsylvania State University, 234 Leonhard Building,  
University Park, PA, 16802, United States

Static delivery vehicle routing problem is difficult to apply in urban transportation network due to the several reasons. For example, traffic conditions are changed dynamically. In addition, it is difficult to adapt the other path options. To handle these problems, we consider Markov decision process model. The objective of the model is finding optimal action at a given network condition. Optimal action contains the next location to visit as well as path option that agent will take. We assume fully observable stochastic network conditions when the agent make a decision. In this presentation, we define the mathematical model and introduce simple approximate method.

## ■ WB34

North Bldg 223

### Game Theory I

Contributed Session

Chair: Xicheng Yin, Tongji University, 1239 Siping Road, Shanghai,  
P.R., China

#### 1 - Design of Third Party Intervention Strategy in the Conflict

Haiyan Xu, Nanjing University of Aeronautics and Astronautics,  
23 Avenue Guy de Collongue, Nanjing, 69130, China

This research aims to provide the intervention strategy for the third party to mediate the conflict between two decision makers. The intervention strategy is designed to minimize the adjustments of preferences of the two DMs to make them achieve an equilibrium easily based on the graph model for conflict resolution. Therefore, an integer program is constructed with the constraints based on the requests. The solutions of this model can assist the third party to guide DMs to be stable for a given state.

#### 2 - Compensation Regulation and More Hazard in Banking

Minglong Zhou, NUS, 1 Business Link, Singapore,  
Jussi Keppo

We model banking industry as a three stage asymmetric game between regulators, banks, and bankers. The regulators affect banks and bankers' incentives by using different compensation regulations. We identify conditions under which different compensation regulations are effective. Our results also explain observed behavior in the industry.

#### 3 - Online Privacy and Information Disclosure by Consumers

Shota Ichihashi, Stanford University, 579 Serra Mall, Stanford, CA,  
95051, United States

I study the welfare and price implications of consumer privacy. A consumer discloses information to a multi-product firm, which learns about his preferences, sets prices, and makes product recommendations. While the consumer benefits from accurate product recommendations, the firm may use the information to price discriminate. I show that the firm prefers to commit to not price discriminate to encourage information disclosure. However, this commitment hurts the consumer, who could be better off by precommitting to withhold some information. In contrast to single-product models, equilibrium is typically inefficient even if the consumer can disclose any information about his preferences.

#### 4 - Prospect Games and Regulated Prospect Games: Modeling Adversarial Inducement

Brian J. Lunday, Air Force Institute of Technology, 2950 Hobson  
Way, Wright Patterson Air Force Base, OH, 45433, United States,  
William Caballero, Richard F. Deckro

Populations are often confronted with multiple entities simultaneously attempting to influence their actions. Herein, we describe two new game theoretic frameworks, denoted as prospect games and regulated prospect games, that respectively model (a) the interactions of competing persuaders affecting a

populace and (b) the actions of a regulating agent to alter such a framework, and illustrate civil applications thereof. We provide a modeling framework for competitive persuasion operations, develop model variants that respectively correspond to scenario-specific modifications, and identify and selectively illustrate practical solution methods for the suite of models.

### 5 - Agent-based Opinion Formation Modeling in Social Network: A Perspective of Social Psychology and Evolutionary Game Theory

Xicheng Yin, PhD Student, Tongji University, Shanghai, 200092,  
China, Hongwei Wang, Pei Yin

We propose an agent-based online opinion formation model based on attitude change theory, group behavior theory and evolutionary game theory in the perspective of sociology and psychology. Three factors influence the persuasion process, including credibility of the leaders, characteristic of the recipient, and group environment. The model is applied to Twitter to analyze the influence of topic type, parameter changing, and opinion leaders on opinion formation. Results show that controversial topic shows greater uncertainty and sustainability. The ratio of benefit to cost has a significant impact on opinion formation. Celebrities are more capable of influencing public opinion than experts.

## ■ WB35

North Bldg 224A

### Hub and Air Cargo Operations

Sponsored: Aviation Applications

Sponsored Session

Chair: Farshid Azadian, Embry-Riddle University, College of Business,  
Daytona Beach, FL, 32114, United States

#### 1 - A Sustainable-resilient Network Design for Indian Aviation Sector

Suresh Kumar Jakhar, Indian Institute of Management Lucknow,  
IIM Lucknow Campus, Lucknow, 226013, India

We propose a capacitated multiple allocation p-median hub location problem. The multiple objective functions consider economic, environmental, and social performance goals. We deal with inherent uncertainty in parameters by using mean absolute deviation and fuzzy possibilistic-stochastic programming. The proposed formulation is used in a case study of Indian aviation industry.

#### 2 - Comparing the Fixed and Flexible Hub Assignment Approaches When Solving the Express Shipment Service Network Design Problem

Jose Miguel Quesada, Universit  catholique de Louvain,  
Av Moliere 325, Uccle, 1180, Belgium, Jean-Charles Lange,  
Jean-Sebastien Tancrez

When solving the Express Shipment Service Network Design (ESSND) problem, most models from the literature assume that the assignment of packages to hubs is fixed. However, there are no methods in the literature to determine such hub assignments. We first develop an exact model that integrates the hub assignment decisions into the ESSND problem. Then, we develop 4 heuristic methods to determine the hub assignments for the fix hub assignment approach. Finally, we compare the fix and flexible hub assignment approaches with realistic instances, showing clear advantages for the flexible approach.

#### 3 - Unpaired Pickup and Delivery Problem with Time Dependent Assignment Costs

Farshid Azadian, Associate Professor, Embry-Riddle University,  
Daytona Beach, FL, 32114, United States

This study considers a freight forwarder's operational implementation of alternative access airport policy in a multi-airport region for cargo transportation. Given a set of heterogeneous air cargo customers, the forwarder's problem is to simultaneously select air cargo flight itineraries and schedule the pickup and delivery of customer loads to the airport(s). This problem is formulated as a novel pickup and delivery problem, where the delivery cost is both destination and time dependent. A mixed-integer linear model in presented and an efficient solution method based on decomposition is developed. The performance of the solution algorithm is evaluated by computational experimental study.

## ■ WB36

North Bldg 224B

### Inventory Management II

Contributed Session

Chair: Emre Berk, Bilkent University, Faculty of Business Administration, Ankara, 06533, Turkey

#### 1 - Inventory Model for Fresh Produce Considering Price, Freshness, and Displayed Stock Level Dependent Demand

Bhavin J. Shah, Associate Professor, Indian Institute of Management, Indore, Faculty Office # C-206, First Floor, Prabandh Shikhar, Indore - Madhya Pradesh, 453556, India, Hasmukh Gajjar

An inventory model is proposed for fresh produce items to determine unit price, cycle time, displayed stock level, and ending inventory to maximize retailer's total profit. Demand is considered to be deterministic and dependent on price, freshness and displayed stock. Numerical examples are presented to highlight the theoretical results.

#### 2 - Spare Parts Inventory Control with Phase-out Returns and Additive Manufacturing

Yayun Jin, North Carolina State University, Raleigh, NC, 27607, United States, Russell Edward King, Donald Paul Warsing, Semra Sebnem Ahiska

Manufacturers are concerned with the inventory control of spare parts in the final phase of their service lifecycle. The final phase starts when the specified tooling to produce this type of spare parts is disposed after the final production run, and it ends when the products associated with the spare parts are no longer used. We consider the inventory control with stochastic demand and deterministic returns where the stock is replenished by newly manufactured parts, phase-out returns and repaired defective parts. We formulate this problem as a Markov decision process model and based on the characterization of the optimal policy, we propose newsvendor-like heuristic policies that perform very well.

#### 3 - Newsvendor Model Revisited with Crowdfunding

Emre Berk, Bilkent University, Faculty of Business Administration, Ankara, 06533, Turkey

I revisit the classical newsvendor model in the presence of financing uncertainty. I consider reward-based P2P lending. The decision maker faces the possibility of not being able to raise enough capital to successfully launch the product. The financing phase is modeled in a two ways - each corresponding to a market segmentation. The impact of financing uncertainty on optimality is examined analytically and numerical examples are provided.

## ■ WB37

North Bldg 225A

### Applied Probability and Healthcare

Sponsored: Applied Probability

Sponsored Session

Chair: Jing Dong, Columbia University, New York, NY, 60208, United States

#### 1 - Time-varying Tandem Queues with Blocking: Comparing Operating Mechanisms in Hospital Networks

Noa Zychlinski, Avishai Mandelbaum, Petar Momcilovic

We focus on the mechanisms of Blocking After Service (BAS) and Blocking Before Service (BBS), in time-varying many-server queues in tandem. BAS arises in hospitals when patients must remain in their current ward even after completing their treatment, since there is no available bed at the next ward to which they are referred. BBS arises in short procedures such as cataract surgery, cardiac catheterization and hernia repair: the procedure begins only when there is an available bed for the patient in the recovery room. Using reflection analysis, we develop the fluid limit for each mechanism. This gives rise to design/operational insights including a performance comparison between the two mechanisms.

#### 2 - Forecasting Arrivals and Occupancy Levels in an Emergency Department

Xiaopei Zhang, Columbia University, New York, NY, 10025, United States, Ward Whitt

This is a sequel to Whitt and Zhang (2017), where we developed an aggregate stochastic model of an emergency department. The new work here focuses on forecasting future daily arrival totals and predicting hourly occupancy levels, given recent history. By involving more data, we identify i) long-term trends in both the arrival process and the length-of-stay distributions and ii) dependence among successive daily arrival totals. Both highly structured models and flexible machine learning methods are explored. We find that a SARIMAX time-series model is most effective. We then combine our previous ED model with the arrival prediction to create a real-time predictor for the future ED occupancy levels.

#### 3 - Value-based Healthcare Associated Infection Prevention Scheme Using Machine Learning

Elioth Sanabria, Columbia University, New York, NY, United States, David D. Yao

Healthcare associated infections (HAI) cost 9.8 billion USD per year, making them a major problem for the US healthcare system. We present a machine learning (ML) aided scheme to give patient targeted preventive measures. This scheme aligns the economic incentives of the hospital to give preventive measures to more patients while reducing overall infection costs. We provide probabilistic guarantees on the economic performance of the scheme for any fitted ML model based on a combination of machinery from NP (Neyman Pearson) classification and VC (Vapnik Chervonenkis) theory. We illustrate the methodology with data of hospital admissions between 2009 and 2016 at NewYork Presbyterian Hospital.

#### 4 - On Modeling Patient-flow Dynamics in the Obstetrics and Gynecology Inpatient Unit

Jing Dong, Columbia University, New York, NY, 60208, United States, Yue Hu, Ohad Perry

We study the patient flow dynamics of the Obstetric and Gynecologic inpatient unit of a large teaching hospital in the US. The model we build is easy to calibrate, highly interpretable and captures the main features of patient flow dynamics in the unit. We also study the day-of-the-week effect on the occupancy level and provide key insights on modeling and managing hospital queues.

## ■ WB38

North Bldg 225B

### Games, Learning and Networks

Sponsored: Applied Probability

Sponsored Session

Chair: Lei Ying

#### 1 - Delay Asymptotics and Bounds for Multi-task Parallel Jobs

Weina Wang, Carnegie Mellon University, Pittsburgh, PA, United States, Mor Harchol-Balter, Haotian Jiang, Alan Scheller-Wolf, R. Srikant

Motivated by file retrieval in cloud storage systems, we study a problem where jobs consist of multiple tasks and a job is completed only when all of its tasks are completed. The goal is to characterize the tail probabilities of job delay. However, this is a difficult problem whereas computing tail probabilities of task delays is relatively easy. By proving that the task delays at the various servers are associated, we show that assuming independence among task delays yields upper bounds on the tail probabilities of job delay. We then further show that the job delay converges to this upper bound in an asymptotic regime where the number of servers grows and the number of tasks in a job is also allowed to grow.

#### 2 - Bayesian Learning with Random Arrivals

Randall Berry, Northwestern University, Department of EECS, 2145 Sheridan Road, Evanston, IL, 60208, United States, Tho Le, Vijay Subramanian

We consider the impact of uncertainty about agent arrivals on a model of Bayesian observational learning. We study a discrete-time model in which in each time-slot, an agent may randomly arrive. Agents who arrive have the opportunity to buy a given item. If an agent chooses to buy, this action is recorded for subsequent agents. However, the decisions of agents that choose not to buy are not recorded. Hence, if no one buys in a given slot, agents are unaware if this was due to no agent arriving or an agent choosing not to buy. We study the impact of this uncertainty on the emergence of information cascades.

#### 3 - Heavy Traffic Delay Analysis in Data Center Networks

Siva Theja Maguluri, Georgia Institute of Technology, Atlanta, GA, 30339, United States, Daniela Hurtado Lange

The drift method has been recently developed to study queueing systems in heavy traffic. This method was successfully used to obtain the heavy traffic scaled sum queue lengths in data center networks, even when the so-called complete resource pooling condition is not satisfied, i.e., when there is more than one bottle-neck resource. In this talk, I will present a novel view of the drift method. Using this view, we will present recent developments in obtaining the complete distribution of the queue lengths in heavy-traffic.

#### 4 - Achieving Small Delay in Data Center Networks

Carolyn Beck, University of Illinois, Urbana, IL, United States, Dimitris Katselis, R. Srikant, Weina Wang

We will consider packet-level and file-level models of data center networks. For both models, we will explore whether simple resource allocation schemes can achieve order-optimal delays.



## ■ WB39

North Bldg 226A

### Recent Advances in Simulation Analysis Methodology

Sponsored: Applied Probability

Sponsored Session

Chair: Eunhye Song, Penn State University, University Park, PA, 16802, United States

#### 1 - Mo-score for Multi-objective Ranking and Selection

Eric Applegate, Purdue University, West Lafayette, IN, 47907, United States, Guy Feldman, Susan R. Hunter, Raghu Pasupathy

Consider the context of selecting Pareto-optimal systems from a finite set of systems based on multiple stochastic objectives. We characterize the asymptotically optimal sample allocation that maximizes the rate of decay of the probability of misclassification, and we provide a multi-objective SCORE (MO-SCORE) allocation for use when the number of non-Pareto systems is large relative to the number of Pareto systems. The MO-SCORE allocation exploits phantom Pareto systems in high dimensions, which we find using a dimension-sweep algorithm.

#### 2 - Effort Allocation and Statistical Inference for Multistart Stochastic Gradient Descent

Saul Toscano, Cornell University, Peter Frazier

Multistart stochastic gradient descent methods are widely used for gradient-based stochastic global optimization. However these methods seem to waste computational resources: when several starts are run to convergence at the same local optimum, all but one fail to produce useful information; when a start converges to a local optimum worse than an incumbent solution, it fails to produce useful information. We propose a rule for allocating computational effort across starts, which allocates more resources to the most promising starts. This allocation rule is based on a new statistical model, which agrees with known convergence rates for SGD. Numerical results show the effectiveness of our rule.

#### 3 - Online Quantification of Input Uncertainty for Parametric Models

Enlu Zhou, Georgia Institute of Technology, 755 Ferst Drive NW, Atlanta, GA, 30332-0205, United States, Tianyi Liu

It has become increasingly important to assimilate “online data that arrive sequentially in time for real-time decision. Input uncertainty quantification in stochastic simulation has been developed extensively for batch data that are available all at once, but little has been studied for online data. We propose a computationally efficient method to incorporate online data in real time for input uncertainty quantification of parametric models. We show finite-sample bounds and asymptotic convergence for the proposed method, and demonstrate its performance on a simple numerical example.

#### 4 - Efficient Simulation Design for Risk Management of Large Variable Annuity Portfolios

Ben Feng, University of Waterloo, 217 Holbeach Cres, Waterloo, ON, N2J 4Y3, Canada

Variable Annuities (VAs) are popular insurance products in practice. Monte Carlo simulation is usually required to value VA contracts due to their complexities. However, computations required for valuation of every contract in a large VA portfolio via standard MC could be prohibitively expensive. We develop and examine experiment designs that can significantly improve the efficiency of simulation experiments for large VA portfolios. We also identify pitfalls in some of the existing methods and propose corresponding improvements. We show that the proposed simulation procedure has both higher accuracy and lower computational requirement than the state-of-art procedures.

## ■ WB40

North Bldg 226B

### Practice – Modeling and Optimization for Decision Making I

Contributed Session

Chair: Bjarni Kristjansson, Maximal Software Inc., Arlington, VA, 22201, United States

#### 1 - Optimize Urban Agriculture to Address Food Deserts in Semi-arid Areas

Daoqin Tong, Associate Professor, Arizona State University, School of Geographical Sciences and Urban Planning, 975 S. Myrtle Ave., Tempe, AZ, 85287, United States, Qing Zhong, Courtney Crosson

Accessing to healthy, affordable food remains a great challenge in many neighborhoods, leading to the existence of food deserts. Recently, urban agriculture has been identified as an important strategy to help address urban food deserts. However, producing food in the urban setting can be challenging due to limited land availability and high water cost. This paper develops a spatial optimization model to integrate rainwater harvesting, urban municipal land

availability (including soil capacity) and local nutritional needs to evaluate the potential impact of urban food systems in the growing urban Southwest.

#### 2 - Long-term Production Planning Under Demand Uncertainty

Joost T. de Kruijff, Eindhoven University of Technology, Den Dolech 2, Eindhoven, 5600 MB, Netherlands, Nico P. Dellaert, Cor A. Hurkens, Ton de Kok

We focus on long-term production planning. Where mid-term production planning coordinates the release of materials and capacity aiming to minimize the costs of inventory and backlog given the demand, long-term planning focusses on decisions regarding investments in resources and materials to support long-term sales. Taking into account the uncertainty in the long-term sales, we make a tradeoff between revenue creation and investments in capacity and/or inventory. These investments do not take effect immediately; we explicitly take into account the possibility to change plans when we learn more about the future. We base our modelling on practices in the high-tech low-volume industry.

#### 3 - Nonconvex Discrete Optimization Approach for Highdimensional Regression

Yuji Nakagawa, Professor, Kansai University, Department of Informatics, 2-1-1 Ryozanji-Cho, Takatsuki-City, 569-1095, Japan, Yoshiko Hanada, Youichi Takenaka, Youichi Takenaka, Chanaka Edirisinghe

In high-dimensional regression, where the number of explanatory variables is much larger than the sample size, a statistical problem known as the ‘curse of dimensionality’ arises. The strategy of performing all possible regressions is computationally-impractical. We model using non-convex discrete optimization to minimize MSE. We describe an application involving a large number of SNPs in genomic studies for cancer detection.

#### 4 - Using Json and Nosql Databases to Deliver Data for Deploying Optimization Models on the Cloud

Bjarni Kristjansson, Maximal Software Inc., 2111 Wilson Boulevard, Suite 700, Arlington, VA, 22201, United States

When preparing optimization models for deployment, it is often not the formulation of the model or the solving that is the most difficult part, but rather how to organize and deliver the data efficiently to the model. Using modeling languages, this problem can be alleviated by importing data directly from SQL databases and spreadsheets, but this is still not easy enough. In this presentation, we will demonstrate how using the JSON data format can be particularly well suited for organizing optimization data. Furthermore, using NoSQL databases such as MongoDB and CouchDB, which are very efficient at storing dynamic data, give the model developer new opportunities for deploying optimization on the cloud.

## ■ WB41

North Bldg 226C

### DA Arcade (Technology)

Sponsored: Decision Analysis

Sponsored Session

Chair: Gilberto Montibeller, Loughborough University, School of Business & Economics, Loughborough, LE11 3TU, United Kingdom

#### 1 - Technology Adoption in a Declining Market

Maria Lavrutich, Norwegian University of Science and Technology, Trondheim, Norway

Rapid technological developments are inducing the shift in consumer demand from existing products towards new alternatives. When operating in a declining market, the profitability of incumbent firms is largely dependent on the ability to correctly time the introduction of product innovations. This paper considers the optimal innovation investment in the context of the declining market. We study the problem of a firm that has an option to undertake the innovation investment and thereby either to add a new product to its portfolio or to replace the established product by the new one. We are able to quantify the value of the option to adopt a new technology, as well as the optimal timing to exercise it.

#### 2 - Integrated Scenario based Robust Planning Approach for Foresight in Blockchain Technology

Leili Soltanisehat, The University of Oklahoma, 815 Russell Circle, E. Brooks St, Norman, OK, 73071, United States, Reza Alizadeh

Blockchain faces major future challenges related to technological, economic, social, and probably political aspects. Here we present a scenario-building framework based on the Global Business Network method to help blockchain to develop more resilient conservation policies when it faces unpredictable and external uncertainties. The approach combines several foresight methods such as Delphi, Political, Economic, Social, and Technological analysis, and Cross-Impact Analysis.

### 3 - The Impact of Product Recall on Advertising in a Duopoly Market

Arka Mukherjee, PhD Candidate, Concordia University, Montreal, QC, H3H 0A1, Canada, Satyaveer S. Chauhan

Product recalls negatively affect the brand image of a responsible firm. Brand image is positively influenced by advertising. We study the optimal advertising strategies of firms in a duopoly environment with an impending product recall. We find that the optimal advertisements for both the firms are dependent on several parameters like initial brand value, pre-crisis and post-crisis profit margin, advertising effectiveness, damage effect of the recall and the recall probability.

### 4 - Modeling the Value of Agents in Supply Chains of Malaria Rapid Diagnostic Test Kits with Decision Analysis

Gilberto Montibeller, Professor of Management Science, Loughborough University, School of Business & Economics, Loughborough, LE11 3TU, United Kingdom

Malaria poses one of the greatest global health challenges. Accurate malaria diagnosis, with rapid diagnostic tests (RDTs), is critical for treating the disease. In this project we developed and deployed a multi-attribute value model for agents along the RDT kit supply chain (manufacturers, first line buyers, and retailers) in Uganda. The model represents the different priorities, incentives, and preferences of each agent in the supply chain and supported the design of high value bundles for RDT kits. The decision analysis provided a systematic evaluation of alternatives and enabled reflection and learning among the stakeholder.

## ■ WB42

North Bldg 227A

### Queueing Models

Contributed Session

Chair: Iqra Ejaz, Texas A&M University, Bryan, TX, 77801, United States

#### 1 - Determining the Size of Oscillations in Queues with Customer Choice and Delayed Information

Sophia Novitzky, Cornell University, 136 Hoy Road, Ithaca, NY, 14850, United States

With the advancement of online technologies, it is common for the service systems to provide waiting time or queue length information to customers. This information allows the customers to determine whether to remain in line or in the case of multiple lines, which line to join. However, there is usually a delay associated with the waiting time information: either the information is not provided in real time or it takes the customers travel time to join the service after having received the information. Previous work shows that if these delays are large enough, unwanted oscillations in the queue lengths can occur. In this paper, we develop two methods for approximating the amplitude of these oscillations.

#### 2 - Dynamically Scheduling and Maintaining a Flexible Server

Jefferson Huang, Assistant Professor, Naval Postgraduate School, Monterey, CA, United States, Douglas Down, Mark E. Lewis, Cheng-Hung Wu

Advances in sensing technologies have made condition-based maintenance (CBM) in flexible manufacturing systems more economically feasible. We consider the problem of jointly making CBM and scheduling decisions for a server in such a system. In the context of a queueing model of this problem, we show that a natural scheduling heuristic can be extremely suboptimal. We also provide conditions under which one can restrict the search for an optimal policy to policies that (1) schedule according to a static priority rule, and (2) exhibit a certain monotonicity property with respect to the maintenance decisions.

#### 3 - Three-moment Approximation for the Mean Queue Time of a GI/G/1 Queue

Kan Wu, Nanyang Technological University, School of MAE, 50 Nanyang Ave, Singapore, 639798, Singapore, Sandeep Srivathsan, Yichi Shen

The approximation of a GI/G/1 queue plays a key role in the performance evaluation of queueing systems. To improve the conventional two-moment approximations, we propose a three-moment approximation for the mean queue time of a GI/G/1 queue based on the exact results of the H2/M/1 queue. The model is validated over a wide range of numerical experiments. Based on the paired t-tests, our three-moment approximation outperforms the two moment ones especially when both service time and inter-arrival time variabilities are greater than one.

#### 4 - Optimization of Nursing Teams with Patient Assignment Using a Queueing Theory Approach

Parisa Eimanzadeh, Wichita State University, Wichita, KS, 67220, United States, Ehsan Salari

Inpatient units are typically staffed with nursing teams that consist of nurses at different skill levels providing care to patients. This research aims at developing staffing models to determine appropriate staff levels and skill mix for the nursing teams by explicitly incorporating the patient assignment decision. In particular, queueing theory and multi-criteria optimization are combined to find the optimal skill-mix configurations of the nursing teams and the corresponding patient

assignments that minimize staffing costs and nurse burnout while ensuring timely delivery of nursing care.

### 5 - An Efficient Algorithm for Non Markovian Two-node Cyclic Network

Muhammad El-Taha, Professor, University of Southern Maine, Department of Mathematics and Statistics, 96 Falmouth Street, Portland, ME, 04104-9300, United States, Bacer Maddah

Computing the steady state probability distribution of a non-Markovian two-node closed queueing cyclic network is known to be computationally challenging. In this talk, we propose a new efficient convolution method that is significantly more efficient than existing algorithms.

### 6 - Condition-based Maintenance of Queues with Degrading Servers for Stochastic Service Times

Iqra Ejaz, Texas A&M University, College Station, TX, 77843, United States, Michelle M. Alvarado, Natarajan Gautam, Nagi Gebräel, Mark Lawley

We derive an analytical model for condition monitoring of a single server queue with Markovian degradation, Poisson arrivals, and general service and repair times. Stability conditions and performance measures (e.g., average queue length, average degradation.) are derived through steady state analysis. An optimal repair decision model is presented that minimizes an objective function with four costs: repair, catastrophic failure, quality and holding. We develop and verify a simulation model, perform a sensitivity analysis, and show insights learned from relaxing underlying assumptions.

## ■ WB43

North Bldg 227B

### Stochastic Optimization I

Contributed Session

Chair: Itir Z. Karaesmen, American University, Kogod School of Business, Room 212, Washington, DC, 20016, United States

#### 1 - Two-stage Bond Portfolio Optimization under Different Scenarios

Nasser Alreshidi, PhD Student, Florida Institute of Technology, 150 W. University Blvd, Melbourne, FL, 32901, United States, Ersoy Subasi, Munevver Mine Subasi, Andras Daniel Prekopa

Following Hodges and Schaefer's (1977) deterministic bond portfolio model, where the objective is to minimize the cost of bond portfolio, the bond portfolio optimization has become one of the attractive areas of research in finance literature. In this work we propose a new bond portfolio model as a two-stage stochastic programming problem, where a decision maker may optimize the cost of bond portfolio, while deciding which bonds to sell, which bonds to hold, and which bonds to purchase from the marketplace based upon present market conditions under different scenarios. We present the application of our model on real-world datasets.

#### 2 - Production and Capacity Utilization Strategies in Supply Chains for Complex Engineered Products

Ashesh Sinha, Kansas State University, Manhattan, KS, United States, Ananth Krishnamurthy

We analyze a multi-product manufacturing systems where individual products can be made either at a shared in-house manufacturing facility or at dedicated facilities of external subcontractors. Using Markov decision process models, we determine the optimal policy and derive the set of conditions that partitions the state space into regions and analytically characterize optimal policies and value function in each region.

#### 3 - A Game-theoretic Two-stage Stochastic Programming Model to Protect Cyber Physical Systems Against Attacks

Clara Novoa, Associate Professor, Texas State University, 601 University Dr, San Marcos, TX, 78666, United States, Khan Sidiqqe, Mina Guirguis, Alireza Tahsini

We present two-stage stochastic programming models that determine the check blocks to assign to measurement signals and controls to secure a cyber physical system (CPS). The models incorporate uncertainty on the number of signals to be protected over the horizon considered and on the effectiveness of the check blocks. We illustrate the superiority of the proposed approach by computing the value of the stochastic solution and by comparing to other assignment strategies. Results are validated with a simulation to emulate a component in the operation of an autonomous vehicle and with experiments on a mini-boiler testbed that operates on a closed loop and interacts with a Matlab-Simulink program.

#### 4 - Integrating Logistics and Bidding Decisions in B2B Markets

Itir Z. Karaesmen, American University, Kogod School of Business, Room 212, Washington, DC, 20016, United States

We build an analytical model for brokers that procure and sell goods in a B2B market. The broker submits bids to procure goods from several suppliers. The outcome of the bids are uncertain. After the goods are procured, they are shipped to meet the customer demand. We show how the optimal bids can be determined and computed.

■ **WB44**

North Bldg 227C

**Operational and Planning Co-ordination for Natural Gas and Electric Power Systems**Sponsored: Energy, Natural Res & the Environment/Electricity  
Sponsored Session

Chair: Ramteen Sioshansi, The Ohio State University, Columbus, OH, 43210, United States

Co-Chair: Antonio J. Conejo, The Ohio State University, Columbus, OH, 43210, United States

**1 - A Combined Repair Crew Dispatch Problem for Resilient Electric and Natural Gas System Considering Reconfiguration and DG Islanding**Zhengshuo Li, Southern Methodist University, Dallas, TX, USA  
Jianhui Wang, Yanling Lin, Bo Chen, Zhaohong Bie

Resilience is an overarching concept that requires combined efforts from interdependent critical infrastructures to achieve. We present a combined repair crew dispatch problem for interdependent electric and natural gas systems. The repair schedule of the two system is coordinated and co-optimized. Both electric system topology reconfiguration and intentional DG islanding are modeled as operational measures to further improve the resilience of interdependent systems. Case studies validate the effectiveness of the proposed method in reducing load shedding and repair duration, and prove that the interdependence has a significant impact on the repair sequence and crew coordination.

**2 - Equilibrium of Interdependent Gas and Electricity Markets with Marginal Price Based Bilateral Trading**

Wei Zheng, Tsinghua University, Beijing, China

This paper studies the marginal price based bilateral energy trading on the equilibrium of coupled natural gas and electricity distribution markets. Convex relaxation is employed to solve a optimal power flow problem. A successive second-order cone programming (SOCP) approach is utilized to solve a optimal gas flow problem. In both problems, locational marginal energy prices are recovered from the Lagrangian multipliers associated with nodal balancing equations. Furthermore, a best-response decomposition algorithm is developed to identify the equilibrium of the coupled energy markets with bilateral gas and electricity trading, which leverages the computational superiority of SOCPs.

**3 - Expansion Planning of Joint Electricity and Gas Networks**Pascal Van Hentenryck, University of Michigan, 1813 IOE  
Building, 1205 Beal Avenue, Ann Arbor, MI, 48108-2117,  
United States, Russell Bent, Seth Blumsack

Recent trends in gas-fired power plant installation has increased the connections between the electric power and natural gas industries. Despite these dependencies, both industries must meet commercial, political, operational and technical requirements that often force the industries to plan and operate in isolation. As a result, undesired situations may arise, such as those experienced by both systems during the winter of 2013/2014 in the northeastern United States. This paper, we consider the technical challenges and present a combined electricity and gas expansion planning model.

**4 - Unit Commitment of Integrated Electric and Gas Systems with an Enhanced SOC Gas Flow Model**Ramteen Sioshansi, Ohio State University, Integrated Systems  
Engineering, 1971 Neil Avenue, Columbus, OH, 43210,  
United States, Antonio J. Conejo, Sheng Chen

Interdependent electric power and gas systems require a coordinated operation framework. This presentation proposes such framework in a form of a unit commitment (UC) model. A second-order cone (SOC) dynamic gas flow model is employed within an UC model, which results in a mixed-integer SOC programming problem. This model is enhanced by using convex envelopes of bilinear terms to tighten the UC solution. Numerical results from two test systems validate the advantages of the proposed enhanced SOC methodology in terms of solution quality and computational efficiency.

■ **WB45**

North Bldg 228A

**Practice – Environment, Energy, and Natural Resources**

Contributed Session

Chair: Chang Liu, Dongbei University of Finance and Economics, No 217 Jianshan St., Shahekou District, Dalian Liaoning, 116025, China

**1 - The Problem of Information: Moral Hazard and Adverse Selection in Illegal Waste Disposal**Sytske Wijnsma, University of Cambridge, Cambridge,  
United Kingdom, Dominique Lauga

The illegal dumping and trafficking of waste is one of the fastest growing areas of organised crime, mainly due to imperfect monitoring driven by incomplete information. In the presence of imperfect monitoring, waste can be misclassified to hide its true nature or it can be illegally dumped to avoid expensive treatment cost. This paper examines firms' behaviour and non-compliance when they operate under incomplete information with respect to the other agents in the chain. Further, we underscore how increased monitoring of trade bans whilst ignoring the impact of incomplete information on firms' behaviour can have unintended consequences on the export of waste the ban was not even intended for.

**2 - The Effective Mobile Phone Producers Green Supply Chain Management Practices in Reducing Co2 Emissions**Yazan Migdadi, Associate Professor, Qatar University, Doha,  
2713, Qatar

The purpose of this study is reporting the effective mobile phone producers green supply chain management practices to reduce CO2 emissions. Quantitative case study methodology was adopted. This study identified a combination of high impact actions in reducing CO2 emissions related to green purchasing, green production, green distribution, green customers' practices, green business travels, green facilities and offices design actions

**3 - The Influences of Public Environmentalism on Air Pollutant Emissions: A Multilevel Analysis across Chinese Prefecture-level Cities**Chang Liu, Professor, Dongbei University of Finance and  
Economics, No 217 Jianshan St., Shahekou District,  
Dalian Liaoning, 116025, China

Public environmentalism is an effective pollution supervision regulation to moderate pollution emissions, especially when the government has deployed accountability for environmental performance. To what extent will public environmentalism attenuate the effects of economic factors on environmental pollution? We estimate the role of public concern on pollution across 285 Chinese cities over 2004 to 2015 based on the hierarchical structure. The empirical results indicate an inverse U relationship, and public concern over environment can make the cities reach the turning points at a low GDP level. This result has important policy implicates to moderate pollution emissions.

■ **WB46**

North Bldg 228B

**Optimal Design and Dispatch of Alternative Energy Systems**Sponsored: Energy, Natural Res & the Environment/Energy  
Sponsored SessionChair: Alexandra M. Newman, Colorado School of Mines, Golden, CO,  
80401, United States**1 - Sub-hourly Dispatch Optimization of Photovoltaic and Concentrating Solar Power Hybrid Systems**William T. Hamilton, MS, Colorado School of Mines, Golden, CO,  
80401, United States, Alexandra M. Newman, Robert Braun

Concentrating solar power (CSP) technologies capture thermal radiation from the sun utilizing a field of solar-tracking heliostats. When paired with inexpensive thermal energy storage (TES), CSP technologies can dispatch electricity during peak-market-priced hours. The hybridization of photovoltaic (PV) and CSP with TES systems has the potential to provide continuous energy production at a lower cost than a PV or CSP system alone. To evaluate a PV-CSP hybrid design, we develop a profit-maximizing mixed-integer linear program that determines a dispatch schedule. We present preliminary results from such model with an emphasis on parametric analysis of system design decisions.



## 2 - Integrating Optimized Dispatch with a Concentrated Solar Power Maintenance Simulation Model

Jesse Wales, Colorado School of Mines, Golden, CO, 80401,  
United States, Alexander Zolan, William Hamilton, Alexandra M.  
Newman, Robert Braun

Concentrating Solar Power (CSP) is an emerging large-scale renewable technology that uses sunlight to heat molten salt, which is stored and can be converted to power using heat exchangers and turbines. We describe a maintenance, failure and repair simulation model that interfaces with an optimization dispatch model for a CSP production plant. We optimize an energy dispatch strategy to maximize profit. We simulate planned and unplanned downtimes based on dispatch decisions from the optimization model to quantify the wear-and-tear impacts from operations.

## 3 - Stochastic Optimization Formulations for Wind Turbine Power Maximization and Extreme Load Mitigation

Yankai Cao, University of Wisconsin-Madison, 2009 Engineering  
Hall, 1415 Engineering Drive, Madison, WI, United States,  
Victor Zavala

We propose stochastic programming formulations to enforce mechanical load requirements in wind turbine controller design procedures. The formulations use a probabilistic constraint that captures the long-term probability of exceeding an extreme load threshold. We use the formulations to find design parameters for pitch angle and torque controllers that maximize power output while constraining long-term extreme loads. The proposed formulations can be cast as large-scale (but structured) nonlinear programming problems (NLPs) that contain up to 7.5 million variables and constraints, and can be solved in less than 1.5 hours on a multi-core computer using existing optimization tools.

## 4 - Real-time Optimization of Chillers with Thermal Energy Storage and Variable Electricity Rates

Landen Blackburn, University of Utah, Salt lake City, UT,  
United States, John Hedengren, Kody M. Powell

As more renewable energy is integrated into the power grid, it is increasingly important to exploit variable electricity pricing structures to minimize commercial utility costs. Using data from one of the University of Utah's chiller plants, equipped with a thermal energy storage tank, a novel technique is proposed to optimize this system in real time, formulated as a Mixed-integer Quadratic Programming problem. Future demand is predicted with reasonable accuracy using historic data and current weather forecasts, and the optimized result can easily be calculated in real time. The approach for solving this optimization problem proves very successful when compared to other standard algorithms.

## ■ WB47

North Bldg 229A

## Sustainable Operations & Development

Contributed Session

Chair: Feiyi Yan, Northwestern Polytechnical University,  
127 West Youyi Road, Xi'an, O, China

### 1 - Eco-investments: Eco-efficiency versus Eco-innovation

Arda Yenipazarli, Associate Professor of Operations Management,  
Georgia Southern University, 2224 College Of Business,  
Department of Logistics & Supply Chain Mgmt, Statesboro, GA,  
30460, United States

We examine environmental investment efforts and whether they should be channeled towards cutting production costs through gains in process-oriented resource productivity (eco-efficiency) or product-oriented eco-differentiation that lowers customers' water/energy/fuel use and related costs (eco-innovation), benefits that justify price premiums, and drive increased market share. While eco-efficiency is easy to pursue with little expertise and capital investment, eco-innovation requires the firm to deal with challenges of managing technology and time-to-market uncertainty.

### 2 - The Impact of Autonomous Vehicles on Traffic Congestion: Is Pooling the Solution to Avoiding Traffic Gridlock?

Sergey Naumov, MIT, Cambridge, MA, 02142, United States

We study the impact of autonomous vehicles (AVs) and ride sharing on traffic volume and road congestion. We develop a dynamic model of travel demand and demonstrate that in the absence of other regulations, the more effective AVs and pooling are at reducing congestion, the stronger is the demand response, offsetting or possibly overwhelming the assumed benefits of AVs. We show that for policies to address the negative externalities of driving effectively, they need to reduce, not increase, the relative attractiveness of driving. Our results have important implications for the design of urban transportation policies.

## 3 - Time Value of Different Information Dimensions on Environmental Technology Adoption

Shadi Goodarzi, Assistant Professor of Operations Management,  
California State University Fullerton, 800 N. State College Blvd,  
Fullerton, CA, 92618, United States, Sam Aflaki, Andrea Masini

We empirically examine the time-dependent impact of different types and channels of information on both the intention to adopt an environmental technology system and the actual adoption decision. The findings have important implications for both policy-making and for technology manufacturing companies that need to optimize their marketing strategy and distribution.

## 4 - Managing Funds in Non-profits: Advertisements, Fundraising and Program Expenses

Nazli Turken, Assistant Professor, Cleveland State University,  
Cleveland, OH, 44107, United States, Janice E. Carrillo,  
Anand Paul

In this paper, we study how non-profits allocate their funds to advertisements, fundraising activities and program expenses to maximize their return on investment. We evaluate the direct and indirect impact of spending on a non-profit's reputation and donations, respectively.

## 5 - An Improved Aggregation Method for Evaluating the Performance of Serial Lines with Unreliable Machines and Finite Buffers

Fei-Yi Yan, Northwestern Polytechnical University,  
127 West Youyi Road, Xi'an, China, Jun-Qiang Wang

Many analytical methods have been developed to evaluate performance of serial lines with unreliable machines and finite buffers. However, these methods cannot perform well in some cases where the machine efficiency is not uniform allocation. To solve this problem, an improved aggregation method that can perform well even in those cases is proposed. First, we demonstrate that the existence of sub-optimal machines causes the lower accuracy of the previous aggregation method. Then, an improved aggregation method is proposed by eliminating the deteriorating effect of sub-optimal machines. This method will help production managers to scientifically evaluate serial lines with higher accuracy.

## ■ WB48

North Bldg 229B

## Joint Session, ENRE/DM: Sustainability Topics in Urban Environments

Sponsored: Energy, Natural Res & the Environment Environment &  
Sustainability

Sponsored Session

Chair: Victoria C. P. Chen, The University of Texas at Arlington,  
Arlington, TX, 76019-0017, United States

### 1 - Project-level Air Quality Assessment for Active Infrastructure

Stephen Mattingly, Associate Professor, University of Texas at  
Arlington, Box 19308, Arlington, TX, 76019-0308, United States,  
Ziaur Rahman, Colleen Casey

Motor vehicle exhaust emissions represent the single largest source of regional air pollution in urban areas. Outdoor physical activity near heavy-traffic is associated with symptoms of respiratory dysfunction, cardiopulmonary disease and even mortality from stroke. At present, project-level air pollution concentration standards do not exist, so the development of air quality performance measures and standards for physical activity will help decide future activity paths and infrastructure priorities. This research creates performance measures for evaluating the relationship between air quality and the physical characteristics of walking and cycling routes.

### 2 - Modeling and Stochastic Bounds on Multi-agent Demand Response

Alireza Fallahi, TX, United States, Jay Michael Rosenberger,  
Victoria C.P. Chen, Wei-Jen Lee

The renewable energy revolution will substantially alter the future energy. With increasing penetration of stochastic renewable energies, the power distributors must respond to an extremely dynamic, complex, and challenging real-time supply-demand balancing problem, which lead to a dramatically different energy market, both operationally and fundamentally in the near future. This research is designed to bridge the knowledge gap. The mathematical model is proposed and bounds of the optimal operational cost are evaluated.

### 3 - Optimization Based Method for Seismic Rehabilitation of Water Pipe Networks

Azam Boskabadi, PhD Candidate, University of Texas at Arlington, Arlington, TX, United States, Jay Michael Rosenberger, Mohsen Shahandashti, Binaya Pudasaini

We introduce a stochastic programming model for water pipe rehabilitation problem with a recourse flow function to maximize the output flow in the subgraph after earthquake. The stochastic programming model starts with an initial rehabilitation policy in water pipes which shows the decision of rehabilitating water pipes before earthquake, then it considers several random scenarios for the broken pipes after earthquake. We use Benders Decomposition in our study, the master problem finds the best X or rehabilitation policy before the earthquake that maximizes the expected SSL, while each recourse problem assigns maximum output flow in the created subgraph.

### 4 - Sustainability Assessment for Green Building

Shirish Rao, University of Texas-Arlington, Arlington, TX, 76019, United States, Victoria C. P. Chen, Jay Michael Rosenberger, Atefe Makhmalbaf, Takuma Mitani

Building structures have significant impact on environment and energy consumption. Buildings can be designed so that their energy consumption is reduced by using energy efficient materials. The “cradle-to-grave” cycle is a criterion for the environmental effects of materials and minimizing this effect along with energy consumption is of great interest. The goal of the research is to compare different experimental designs and statistical modeling methods to help inform our approach for a multivariate, multi-response green building framework. The results of the experiments are studied by using Treed regression and Multi Adaptive Regression Splines techniques to find influential factors.

## ■ WB49

North Bldg 230

### Energy Policy and Planning II

Contributed Session

Chair: Erin Mayfield, Carnegie Mellon University, 5000 Forbes Avenue, Pittsburgh, PA, 15213, United States

#### 1 - Corporate Responses to Public Pressures and Price during an Electric Power Interruption

Shigeharu Okajima, Associate Professor, Osaka University of Economics, 2-2-8 Osumi, Higashiyodogawa-ku, Osaka, 533-8533, Japan

This study investigates corporate electricity consumption behaviors during a power interruption in a natural field experiment. It is found that in general, firms reduce electricity consumption in response to public pressures, but not electricity price increases, and that increasing electricity price is yet effective to reduce electricity consumption of such firms that do not react to public pressures.

#### 2 - Finding Multiple Equilibria in a Dynamic Energy Bilateral Contract Scheduling

Javier Contreras, Universidad Castilla La Mancha, Ciudad Real, Spain, Reinaldo Crispiniano Garcia, Matheus Barbosa, Barbara Macedo, Daniel Monteiro

In the deregulated electricity markets the involved parties, the buyers and the sellers, aim to deliver electricity in time intervals during the contract period to obtain the highest possible profits. This paper implements a model where the parties by a compromise approach achieve a possible equilibria including the Nash and the Raiffa-Kalai-Smorodinski (RKS) ones. An approach in prices and quantities is applied transforming the nonlinear and nonconvex set of the inequalities into a mixed integer linear problem (MILP). A procedure to find all Nash and RKS equilibria is developed by generating “holes added as linear constraints to the feasibility region showing the feasibility of the approach.

#### 3 - A Robust Contingency Constrained Unit Commitment with an N-AK Security Criterion

Jaehee Jeong, Korea Advanced Institute of Science & Technology, Dept. of Industrial and Systems Eng., KAIST, 291 Daehak-Ro, Yuseong-Gu, Daejeon, 305-701, Korea, Republic of, Sungsoo Park

In the power grid systems, the N-k contingency-constrained unit commitment (CCUC) model has been adopted to guarantee the system's reliability. One of the drawbacks of N-k CCUC model is that its robust solution is too conservative. To mitigate this drawback, we propose N-ak CCUC model which excludes some extreme cases with low probability. An economic and reliable robust solution can be achieved by a proper criterion setting. Our model is solved by a Benders' decomposition type algorithm with maximum feasible subsystem cuts. Numerical results on a modified IEEE 118-bus system are reported.

### 4 - Recent Advances in MILP Formulations for the Unit Commitment Problem

Bernard Knueven, Sandia National Laboratories, P.O. Box 5800, MS 1326, Albuquerque, NM, 87185-1326, United States, Jim Ostrowski, Jean-Paul Watson

This paper presents recent work on MILP formulations for the unit commitment problem (UC). UC is that of deciding which power generators to schedule to meet anticipated energy demand, and is of critical importance in the operation of power systems. We review existing MILP formulations along with novel formulations made by combining various ideas from the literature and present a comprehensive computational study of said formulations. In addition, we provide reference implementations of the reviewed formulations in the Pyomo modeling language, along with a library of UC test instances.

### 5 - A Multiobjective Model of Environmental and Labor Market Impacts of Natural Gas Development Decisions in Appalachia

Erin Mayfield, Carnegie Mellon University, Pittsburgh, PA, United States, Jared L. Cohon, Allen Robinson

With the advancement of drilling and fracturing technology and the resulting rapid acceleration of natural gas production, there have been corresponding human health, climate, ecosystem, and labor market impacts. We focus our analysis on Appalachia, a region with a long history of both resource extraction and poverty, as well as, the current location of the highest producing natural gas reservoir in the US. A multiobjective optimization model is formulated in which we optimize spatially-explicit environmental and labor market impacts with respect to decisions regarding the magnitude and timing of natural gas activity. We also incorporate distributive and temporal equity constraints.

## ■ WB50

North Bldg 231A

### Decision Making

Contributed Session

Chair: Gary R. Waissi, Arizona State University, Cave Creek, AZ, 85331, United States

#### 1 - Using Social Media to Advocate and Enable Knowledge Sharing Within Agile Teams

Deepa Umakanth, Arizona State University, Backus Mall, Mesa, AZ, 85128, United States, Gary R. Waissi (adviser)

This paper discusses a case study of using social media to advocate and enable knowledge sharing within agile teams. Knowledge sharing involves sharing of knowledge with employees, within teams and organizations. Social media aide in the sharing and exchange of knowledge. With a good implementation of Agile framework, tools and online processes to share knowledge effectively, a company can grow effectively and will be able to face the competition. The results indicate that knowledge sharing using online tools is easy, fast and is the current trend with Agile frameworks.

#### 2 - Finding a High Quality Initial Solution for the Traveling Salesman Problem (TSP)

Pragya Kaushal, Arizona State University, Tempe, AZ, United States, Gary Waissi

We propose an efficient algorithm to preprocess the fully dense symmetric network to find a good, feasible, solution for the TSP. The algorithm generates a sequence of spanning trees, and using those constructs a “layered network”. This layered network will include a feasible solution for the TSP. This solution can serve as the starting solution, for example, for the TABU search. We hypothesize, that the quality of the initial solution provided by the proposed algorithm will improve the performance of the TABU search in terms of number of iterations required to reach a high level TSP solution.

#### 3 - A Novel Matrix Technique for Finding an Efficient Solution for the Traveling Salesman Problem (TSP)

Gary R. Waissi, Arizona State University, Cave Creek, AZ, 85331, United States

We propose a polynomial algorithm to process the fully dense symmetric network to find a good, feasible, solution for the TSP. The algorithm processes the cost matrix representing the network to generate a feasible TSP tour. One iteration includes making an assignment in a selected row or column, then omitting that row or column from further consideration, declaring the column or row opposite to the first assignment as “tabu”, and thereby reducing the problem size. The matrix reduction and “tabu assignment assure that the process will result into a complete tour.

#### 4 - Determining Catastrophe Insurance Subsidies under Social Network Influence

Shenming Song, Tsinghua University, Beijing, China,  
Chen (Mavis) Wang

Catastrophe insurance is regarded as an effective financial mechanism that transfers post-disaster losses to proactive preparedness investments, despite many practical challenges. We consider a sequential game with three types of players, the government, a private insurer, and a community of networked policy holders, with which we examine the tradeoffs between government subsidies for insurance premiums and post-event subsidies under different characteristics of social network influence. We also explore the benefits of a multi-year insurance contract over consecutive single-year contracts.

## ■ WB52

North Bldg 231C

### Practice - Nonlinear and Dynamic Programming for Applications

Contributed Session

Chair: Luca Bertazzi, University of Brescia, Brescia, 25122, Italy

#### 1 - A One-phase Interior Point Method for Nonconvex Optimization

Oliver Hinder, Stanford, Stanford, CA, 94305, United States,  
Yinyu Ye

The work of Wachter and Biegler suggests that infeasible-start interior point methods (IPMs) developed for linear programming cannot be adapted to nonlinear optimization without significant modification, i.e., using a two-phase or penalty method. We propose an IPM that, by careful initialization and updates of the slack variables, is guaranteed to find a first-order certificate of local infeasibility, local optimality, or unboundedness of the (shifted) feasible region. Our algorithm with closely resembles successful algorithms from linear programming. Experiments also indicate superior robustness and infeasibility detection compared with IPOPT.

#### 2 - Power System Optimization through Joint Placement of Phasor and Flow Measurements

Vahidhossein Khiabani, Assistant Professor, Middle Tennessee State University, Murfreesboro, TN, 37132, United States

We proposed a mathematical method for joint optimal placement of phasor and conventional flow measurements considering the conflicting objectives of Phasor Measurement Units (PMU's) deployment cost, and system reliability. The model places PMUs on a network with a pre-existing conventional measurements, considering zero injection measurements with the goal of complete observability of the system. The proposed approach is tested on IEEE standard bus systems and compared with some models in literature.

#### 3 - Algorithm for Evolutionarily Stable Strategies against Pure Mutations

Sam Ganzfried, Ganzfried Research, Miami Beach, FL, 33139, United States

Evolutionarily stable strategy (ESS) is an important solution concept in game theory which has been applied frequently to biology and even cancer. Finding such a strategy has been shown to be difficult from a theoretical complexity perspective. Informally an ESS is a strategy that if followed by the population cannot be taken over by a mutation strategy. We present an algorithm for the case where mutations are restricted to pure strategies. This is the first positive result for computation of ESS, as all prior results are computational hardness and no prior algorithms have been presented.

#### 4 - Optimization Tools for the Management of Electric Vehicles in Electrical Networks

Rafael Zarate-Minano, Associate Professor, University of Castilla-La Mancha, EIMIA, Plaza Manuel Meca 1, Almaden, 13400, Spain,  
Alberto Flores, Miguel Carrion, Ruth Dominguez

The generalized use of the electric vehicle in industrialized countries could become a reality during the next decade. In this context, it is necessary to carefully analyze different aspects of the interaction between these vehicles and electrical networks. This work explores the combined application of optimization methods and homotopy techniques for the modeling of such interaction. The ability of this combination of techniques to study aspects such as the adequacy and the operation of the existing transmission and distribution networks in a context of large-scale integration of the electric vehicle is discussed.

#### 5 - Dynamic Task Allocation with Learning and Forgetting

Thomas Vossen, University of Colorado-Boulder, Leeds School of Business, UCB419, Boulder, CO, 80309, United States, Peter Letmathe

We consider a setting where tasks arrive randomly over time for possible processing. Incoming tasks can be allocated to (human) resources, whose productivity depends on the number of tasks processed by the resource before (learning) and is impacted by changes in the workforce over time (forgetting). We formulate the task allocation problem as a weakly coupled stochastic dynamic

programming problem, and use a Lagrangian Relaxation approach to derive heuristic allocation policies. We evaluate the flexibility and resilience that emerge from these policies, and analyze how various environmental factors impact performance.

#### 6 - Dynamic Project Expediting in Stochastic Networks

Luca Bertazzi, University of Brescia, Brescia, 25122, Italy,  
Riccardo Mogre

A project manager is in charge of a project. At each time, she needs to decide the effort level to invest in the project. The progress made on the project is random, constituting disruptions or efficiency problems. We formulate a stochastic discrete dynamic programming model for this problem and design an exact algorithm to find an optimal policy. Computational results show that this algorithm is more efficient than the classical exact algorithms Value iteration, Policy iteration and Linear programming.

## ■ WB53

North Bldg 232A

### Joint Session AMD/Practice Curated: Auctions and Mechanism Design Applications

Sponsored: Auction and Marketing Design

Sponsored Session

Chair: Michael O. Ball, University of Maryland-College Park, College Park, MD, 20742-1815, United States

#### 1 - Quantity-contingent Auctions and Allocation of Airport Slots

Yulin Liu, University of California-Berkeley, 107D McLaughlin Hall, Berkeley, CA, 94720, United States, Michael O. Ball, Alexander Estes, Mark M. Hansen

We define and investigate quantity-contingent auctions, which can be used when there exist multiple units of a single product and the value of a set of units depends on the total quantity sold. A quantity-contingent auction determines both the number of items sold and an allocation of items to bidders. We focus on auctions that allocate airport arrival and departure slots. We propose a continuous model and an integer programming model for the associated winner determination problem. Using these models, we perform computational experiments that lend insights into the properties of the quantity-contingent auction.

#### 2 - Strategic Timing and Pricing in On-demand Platforms

Mustafa Dogan, Carnegie Mellon University, 5000 Forbes Avenue, Pittsburgh, PA, 15213, United States, Alexandre Jacquillat, Vibhanshu Abhishek

We design a dynamic pricing and allocation mechanism for service provision in an on-demand platform facing demand stochasticity, heterogeneity across price-sensitive and time-sensitive customers, and information asymmetry. Time is a strategic device to dynamically manage the demand-capacity imbalances; and to provide discriminated service levels. Results suggest that the optimal mechanism depends on the strength of customer heterogeneity and the time preferences of price-sensitive customers. The proposed mechanism increases platform profits as compared to surge pricing policies, and can even provide a Pareto improvement. We also show that higher demand may trigger lower price.

#### 3 - How Efficient is CTOP?

Alexander Estes, University of Maryland, Beltsville, MD, 20705, United States, Farzad Daneshgar, Michael O. Ball

The Federal Aviation Administration sometimes issues traffic management initiatives that restrict the amount of traffic allowed to enter some region of airspace. The Collaborative Trajectory Options Program allows flight operators to specify alternative routes for their flights. The FAA uses the options to more efficiently implement the traffic management initiative. In this work, we compare the efficiency of the current CTOP allocation process and that of a theoretical system-optimal allocation process.

#### 4 - Randomized Mechanism to Coordinate Carriers in Retail Logistics

Paul Karaenke, Technical University of Munich, Department of Informatics (I18), Boltzmannstr 3, Munich, 85748, Germany, Martin Bichler, Stefan Minner

We consider the problem of slot booking by independent carriers at several warehouses and investigate recent developments in the design of electronic market mechanisms promising to address both computational and strategic complexity. Relax-and-round mechanisms describe a class of approximation mechanisms that is truthful in expectation and runs in polynomial time. While the solution quality of these mechanisms is low, we introduce a variant able to solve real-world problem sizes with high solution quality while still being incentive-compatible. We compare these mechanisms to core-selecting auctions, which are not incentive-compatible, but provide stable outcomes with respect to the bids.



## ■ WB54

North Bldg 232B

### BOM Session

Sponsored: Behavioral Operations Management

Sponsored Session

Chair: Xiaobo Zhao, Tsinghua University, Beijing, 100084, China

Co-Chair: Wanshan Zhu, Tsinghua University, Beijing, 100084, China

#### 1 - Forecast Information Sharing with Multiple Suppliers: Trust & Coordination

Meng Li, Rutgers University, Camden, NJ, United States,  
Yang Zhang, Yue Li

The retailer in a complementary goods supply chain considers whether to share its private demand forecast with its suppliers. According to the theoretical benchmark, share or not share does not make any difference, regardless of how many suppliers involved. However our experiment finds that, sharing the forecast may impede the profit of retailer as well as the performance of suppliers, because the heterogeneity in the agents' trust results in a coordination failure. As a result, the retailer may prefer not to share the forecast when facing multiple suppliers.

#### 2 - Impact of Market Information on Buying Decisions: A Behavioral Study

Diana (Yan) Wu, University of Kansas, 1300 Sunnyside Avenue,  
Summerfield Hall Room 345, Lawrence, KS, 66045-7585,  
United States, Kay-Yut Chen

We study how market information influences purchase behavior. Experiments are conducted in which buyers evaluate trade-offs between value uncertainties, likelihood of out-of-stock and price adjustments. We find decisions can be swayed by market information and develop a model to explain behaviors.

#### 3 - Value of High-Quality Logistics: Evidence from a Clash between SF Express and Alibaba

Ruomeng Cui, Emory University, Atlanta, GA, USA, Meng Li,  
Qiang Li.

Consumers regard product delivery as an important service component that influences their shopping decisions on online retail platforms. Failing to ship products to customers in a timely and reliable manner will diminish customer experience and companies' profitability. In this research, we explore how much customers value a high-quality delivery experience when shopping online. Our identification strategy exploits a natural experiment: a clash between SF Express — the largest private logistics service provider with the highest reputation in both speed and reliability in China — and Alibaba - the largest online retail platform in China.

#### 4 - Decision Bias of Strategic Customers with Private Product-value Information: An Experimental Study

Song Yanan, Tsinghua University, Beijing, China, Xiaobo Zhao,  
Wanshan Zhu

We consider strategic customers who compete for limited stock of a product due to rationing. We conduct a laboratory experiment to study the customers' decisions, and find that, less customers wait for discount than predicted when stock quantity is high; but slightly more customers wait when stock quantity is low. Behavior models reveal that this result is caused by the decision biases of bounded rationality and risk aversion. These findings imply that retailers should discreetly use rationing because the decision biases of strategic customers benefit retailers under light rationing, but hurt them under heavy rationing.

## ■ WB56

West Bldg 101A

### Joint Session HAS/Practice Curated: Data Science in Health Care Operations Research

Sponsored: Health Applications

Sponsored Session

Chair: Jay Michael Rosenberger, University of Texas-Arlington, Arlington, TX, 76019, United States

#### 1 - Parameter Adjustment for Pain Management Treatment Optimization

Amith Viswanatha, The University of Texas at Arlington,  
Arlington, TX, 76013, United States

Mixed Integer Programming (MIP) solvers like CPLEX have several parameters and finding the right parameter settings for a given problem formulation is a challenging task. In this research, we use the design of experiments (DOE) approach to study the influence of CPLEX parameters on the computation time of the pain management optimization model. The orthogonal array design is used to initially screen the significant parameters and a full factorial design is later employed for a detailed investigation on the influence of the selected parameters.

#### 2 - Data-driven Modeling of a Dynamic and Heterogeneous Contact Network for Understanding the Transmission Behavior of Infectious Diseases

Yuan Zhou, University of Texas at Arlington, Arlington, TX,  
United States

Contacts are fundamentally linked to the propagation behavior of human-to-human transmitted diseases. Although several well-known structures of social network have been widely applied in the literature for establishing contacts, such as small-world and scale-free networks, an argument arises concerning the adequacy of such a network in capturing the public contacts that often take place in between individuals who are not socially affiliated. We develop a two-layer network framework for representing both social and public contacts. We will utilize both simulated demographical data that obtained from public data sources and synthetic data that generated for representing human mobility.

#### 3 - A Multi-column Generation Approach for Radiation Therapy Treatment Planning

Gazi Md Daud Iqbal, University of Maryland School of Medicine,  
Baltimore, MD, United States, Jay Michael Rosenberger,  
Hao Howard Zhang

Both intensity modulated radiation therapy (IMRT) and volumetric modulated arc therapy (VMAT) delivery use multileaf collimator to shape the radiation beam in order to achieve modulation. Column Generation approaches have been proposed to generate these shapes (called apertures) to deliver the radiation therapy treatment. Due to large number of candidate columns (feasible apertures), column-generation-based algorithm is computationally expensive, which affects the achievable solution quality within a clinically acceptable time frame. Instead of adding columns one at a time, this research uses a multi-column generation approach to obtain deliverable apertures for both IMRT and VMAT.

#### 4 - Adjusting for Time Varying Confounding with Multiple Treatment Variables

Aera Leboulluec, University of Texas-Arlington, Arlington, TX,  
76013, United States, Nilabh Ohol, Victoria C. P. Chen,  
Jay Michael Rosenberger

Time varying confounding plays a critical role in longitudinal studies. In medical research, estimating an effect of treatment on an outcome of interest is biased due to presence of time varying confounders. This bias results in inconsistent treatment estimates. Most of literature on handling time varying confounding demonstrates the implementation of methods such as inverse probability of treatment weighting to estimate consistent estimates of a single treatment. This presentation extends this approach to multiple treatments and considers both uncorrelated and correlated treatments.

## ■ WB57

West Bldg 101B

### Optimizing Health Policy and Medical Decision Making to Account for Patient Heterogeneity

Sponsored: Health Applications

Sponsored Session

Chair: Diana Maria Negoescu, University of Minnesota, Minneapolis, MN, 55455, United States

#### 1 - Better Infectious Disease Control through Patient Incentive Programs

Sze-chuan Suen, University of Southern California, Los Angeles,  
CA, 90089-0193, United States, Diana Maria Negoescu, Joel Goh

To reduce the number of patients failing to complete long antibiotic regimens, public health departments may offer patients financial incentives to remain on treatment. However, it is unclear how incentive programs should be structured for the greatest societal benefit when resources are scarce. We design an optimal incentive schedule in the context of disease transmission, patient incentive compatibility, and resource constraints. We then demonstrate its application to the case of tuberculosis treatment, where a complete treatment regimen can take over 6 months.

#### 2 - Optimal Decision Making in a Markov Model with Parameter Uncertainty: The Case of Chronic Kidney Disease

M. Reza Skandari, Imperial College Business School, South  
Kensington Campus, Ayrton Rd, Kensington, London, SW7 2AZ,  
United Kingdom, Steven Shechter

We investigate a Markov decision process whose unknown transition parameters are revealed partially through state observation. Decisions are made as the state evolves. We use the model to study the optimal time to start preparing a type of vascular access for chronic kidney disease patients who will need dialysis.

**3 - Optimization-based Subclassification for Causal Inference**

Shasha Han, NUS Business School, National University of Singapore, NUS Business School, Biz 2 Building B1, 1 Business Link, Singapore, Singapore, Joel Goh

We are interested in estimating the individualized and population treatment effects of several drugs respectively. To obtain unbiased estimates, one often need to classify the entire population to several subclasses, such that the covariates between the contrasted treatments are distributed as similar as possible. For the purpose, the study propose an optimal subclassification method.

**4 - Optimal Stopping of Response-adaptive Clinical Trials**

Amir Ali Nasrollahzadeh, Research Assistant, Clemson University, 278 Freeman Hall, Clemson University, Clemson, SC, 29634, United States, Amin Khademi

One advantage of response-adaptive clinical trials is the ability to modify its key elements such as allocation policy, sample size, or stopping decisions while the trial is still in progress. In this study, we consider optimal stopping of Phase-II clinical trials where the objective is to find a "target dose" in a safe dosage range. Response-adaptivity of the design suggests that the decision maker must choose between continuation of the trial with more sampling, termination and moving to a confirmatory phase, and abandoning the trial whenever new observations of patients' responses become available.

**WB58**

West Bldg 101C

**Health Care System Optimization**

Sponsored: Health Applications

Sponsored Session

Chair: Naoru Koizumi, George Mason University, Arlington, VA, 22201, United States

**1 - Optimal Pooling Strategies for Nucleic Acid Testing of Donated Blood Considering Viralload Growth Curves and Donor Characteristics**

Hadi El-Amine, George Mason University, Fairfax, VA, 22030, United States, Ebru Korular Bish, Douglas R. Bish

Blood product safety, in terms of being free of transfusion-transmittable infections (TTIs), is crucial. Nucleic Acid Testing (NAT) technology enables earlier detection of infections but is more expensive, hence, most blood centers administer NAT to pools of blood samples from multiple donors. Since some donor characteristics are uncertain, we develop a chance-constrained model that determines the optimal NAT pool sizes for various TTIs, considering both non-universal (where first-time donors undergo more extensive screening), and universal (i.e., common testing for all donors) strategies, so as to minimize the TTI risk, while remaining within the testing budget with a high probability.

**2 - Interactive Maps for UNOS Data Visualization**

Monica Gentili, University of Louisville, J.B. Speed School of Engineering, Louisville, KY, 40292, United States, Naoru Koizumi, Andrew Rivard

In this talk we will show a web application to visualize UNOS data on heart transplants by means of interactive maps. The available maps will allow the user to visualize different statistics related to the data for different geographic granularity level (transplant center, Organ Procurement Organization, and UNOS region). The statistics will include (but are not limited to) (i) the likelihood of receiving a quality donor heart, (ii) the rate of donor heart offers which were declined (iii) pre- and post-transplant mortality rate. Further developments of the website will be discussed.

**3 - Simulating the Outcome of Blood Incompatible Deceased Donor Kidney Transplantation - Time to Remove the Barrier**

Mehdi Nayeypour, George Mason University, Founders Hall, Fairfax Dr, Arlington, VA, 22201, United States, Keith Melancon, Naoru Koizumi, Karthika Mahendran

ABO incompatible kidney transplantation could be accomplished with good outcomes. Most ABO-i kidney transplants have been accomplished using live donors after preparing recipients weeks before transplantation. We report the first case of successful directed deceased donor ABO-i kidney transplantation other than A2 to B. We desensitized the patient within 24 hours of receiving the organ offer and before performing the transplantation. If our current allocation system could allow for deceased donor ABO-i transplantation, we could significantly curtail kidney discards. We simulated this policy by using KPSAM and witnessed lower wait times and better outcomes.

**WB59**

West Bldg 102A

**Joint Session HAS/DM: Healthcare Analytics**

Sponsored: Health Applications

Sponsored Session

Chair: Krista Foster, University of Pittsburgh, Pittsburgh, PA, 15217, United States

Co-Chair: Zlatana Dobrilova Nenova, University of Denver, Englewood, CO, 80113, United States

**1 - Assessing Multi-modality Breast Cancer Screening Strategies for High-risk Populations**

Caglar Caglayan, PhD Candidate, Georgia Institute of Technology, 755 Ferst Drive NW, ISyE Main Building #321, Atlanta, GA, 30332, United States, Turgay Ayer, Donatus U. Ekwueme

Women with BRCA 1/2 gene mutations and family history of breast or ovarian cancer are at higher risk for breast cancer. For these women, the use of ultrasound (US) and MRI might address some of the limitations of mammography, the standard modality for average-risk women. Currently, there is no consensus on the optimal use of these technologies. We propose a population-dynamics based optimization approach for the multi-modality breast cancer screening problem for the high-risk population. We develop a Markov model to capture the disease progression in high-risk women, and formulate a mixed integer linear program to identify optimal structured strategies that are practical for implementation.

**2 - Approximate Dynamic Programming for a Dynamic Appointment Scheduling Problem**

Zlatana Dobrilova Nenova, University of Denver, Denver, CO, 80113, United States, Dan Zhang, Manuel Laguna

We consider a dynamic appointment scheduling problem. There are multiple patient classes with associated arrival rates, cancellation rates, and no-show probabilities. Patients arrive and make appointment requests over time. The provider can either assign the patient to an appointment slot or reject patients. Overbooking is allowed. The objective is to balance patients' rejection and waiting costs, and the doctor's idle- and overtime costs. Patients may cancel appointments or no-show. The problem is formulated as a finite-horizon Markov decision process and solved using an approximate policy iteration algorithm. We test the solution method on problem instances constructed from clinic data.

**3 - Matching Emergency Physicians and Apps to Meet Patient Demand: Quasi Real-time Scheduling for Improved Patient Satisfaction and Resource Deployment**

Krista Foster, University of Pittsburgh, Pittsburgh, PA, 15217, United States, Jennifer S. Shang

We study the current roles of advanced practice providers in emergency departments throughout a large multi-facility network and identify conditions under which the addition of advanced practice providers would benefit hospitals (reduce costs) and patients (reduce length of stay). We propose a model to optimally staff hospitals with emergency physicians and advanced practice providers to meet patient demand.

**4 - A Spatial Model of the Opioid Epidemic in California**

Sema Nur Kaynar Keles, UCLA Anderson School of Management, Los Angeles, CA, United States, Elisa Frances Long

With more than 67,000 overdose deaths in 2017 in the United States including nearly 5,000 deaths in California, additional efforts to mitigate the opioid crisis are urgently needed. We propose a spatial "epidemic model of opioid use to forecast new opioid prescription rates, opioid addiction, cessation, and overdose death rates in California. Such a model could be used to prioritize key populations and allocate limited resources (eg, naloxone) most efficiently.

## ■ WB60

West Bldg 102B

### Dynamic Resource Allocation Problems in Healthcare

Sponsored: Health Applications

Sponsored Session

Chair: Shan Liu, University of Washington, Seattle, WA, 98195-2650, United States

#### 1 - Resource Allocation for Hepatitis C Elimination

Qiushi Chen, PhD, Penn State, University Park, PA, United States, Turgay Ayer, Jagpreet Chhatwal

More than 70 million people are chronically infected with hepatitis C virus (HCV) globally. With the recent availability of new treatments, the World Health Organization (WHO) set an ambitious target to eliminate HCV by 2030. However, high treatment cost and unawareness of infection remain major barriers to elimination. In this study, we develop an HCV transmission model that aids in optimal allocation of resources to scale-up HCV screening and treatment that can lead to HCV elimination. We present the optimal allocation policies in different health care settings and target population profiles.

#### 2 - Optimal Control of an Infectious Disease with Drug Resistance

Naveed Chehraz, McCombs School of Business, 2110 Speedway, Stop B6000, Austin, TX, 78712, United States, Lauren Cipriano, Eva A. Enns

We study the optimal treatment policy for an SIS-type infectious disease with drug resistance. We prove that the optimal policy is bang-bang with a single switching time and the optimal value function may not be Lipschitz continuous. Using numerical analysis, we demonstrate that the optimal policy changes form when the disease transmission rate is a function of disease prevalence (e.g., as a result of social distancing). Our solution approach can be generalized to other control problems.

#### 3 - Prevention of Seasonal Influenza Outbreak via Healthcare Insurance

TingYu Ho, University of Washington, Seattle, WA, 98125, United States, Zelda B. Zabinsky, Paul A. Fishman, Shan Liu

To prevent the outbreak of seasonal influenza, we develop an integrated insurance mechanism, including vaccination incentives and cost-sharing policies, and formulate the dynamic interaction between a single insurer and multiple insureds as a Stackelberg vaccination game. We implement agent-based simulation modeling with active learning and simulation optimization to determine the interventions that control the spread of flu. Results indicate that incentives and cost-sharing can effectively improve vaccination uptake and maintain low incident rate even with a highly contagious flu.

#### 4 - Allocating Resources for Outreach Programs in Infectious Disease Systems with Information Propagation

Sze-chuan Suen, University of Southern California, Los Angeles, CA, 90089-0193, United States, Brian Wilder, Milind Tambe

Outreach programs play an integral role in infectious disease control by increasing disease awareness, screening rates, and treatment uptake. Outreach campaigns may rely on information propagation through word of mouth and social media (viral marketing), which can exponentially expand the reach of the original outreach message to preferentially reach targeted groups. We study the optimal allocation of limited outreach resources in the context of tuberculosis in the context of a heterogeneous population with such information spread.

## ■ WB61

West Bldg 102C

### Supply Chain Optimization I

Contributed Session

Chair: Zhaowei Hao, National University of Singapore, Singapore 119245, Singapore

#### 1 - Coherence of Demand Forecasting: Application to Tompkins International Company

Sajjad Taghiyeh, North Carolina State University, Raleigh, NC, 27606, United States, David Lengacher, Robert Handfield

We intend to develop a robust multi-tier multi-phase forecasting model for a third-party logistics company. Demands can be represented as the volume of individual Stock Keeping Units (SKUs), and the total volume of SKUs in each distribution center (DC). We aim to use these forecasts and find the aggregation of them to provide a more accurate demand forecasting framework.

#### 2 - A Bi Objective Production Planning and Scheduling Model Dealing with Reworking the Perishable Items in a Parallel Machine System

Elham Taghizadeh, PhD candidate, Wayne State University, Detroit, MI, 48202, United States, Farshid EvazAbadian, Setareh Torabzadeh, Abdollah Mohammadi

Production systems could always struggle with defective products which can be due to human error, machine break-down, and imperfect production system. Rework is one of the strategies to deal with this issue; rework planning involves the production planning and scheduling of the defected items along the master production planning. This paper presents a multi-objective mathematical model to determine how the work and rework must be scheduled in a parallel machine system for a perishable product. The model objective functions are the minimization of cost and makespan. A linear model is developed and numerical experiments are done based on a case study from the literature, which concerns a biopharmaceutical industry. To find out the importance of each parameter, a sensitivity analysis of the results on varying model parameters is presented as well.

#### 3 - Dynamic Capacity Planning and Matching: A Distributionally Robust Approach

Zhaowei Hao, National University of Singapore, Singapore, 119245, Singapore, Long He, Zhenyu Hu, Jun Jiang

In this paper, we develop a distributionally robust model to study how a firm makes initial capacity and allocation decisions with upgrading in a multi-product multi-period setting. Using the enhanced linear decision rule (ELDR), we derive a tractable approximation, and develop a theoretical performance guarantee in solving the robust model. Finally, our numerical study shows the performance and computational efficiency of the ELDR solution in benchmark with the solution from dynamic programming.

## ■ WB62

West Bldg 103A

### Joint Session DM/Practice Curated: Data Science in Health Care II

Sponsored: Data Mining

Sponsored Session

Chair: Mehrad Bastani, Stanford University, Mountain View, CA, 94040, United States

#### 1 - Predicting Post Operative Survivability of Lung Cancer Patients a Machine Learning Approach

Alireza Fazli Khalaf, Student, Binghamton University, Vestal, NY, 13905, United States, Yong Wang

Thoracic surgery is one of the treatment options for lung cancer. Risk measurement of such surgery is critical to choose the operation or not. In this paper, one-year survivability of lung cancer patients after a thoracic surgery is investigated using machine learning techniques. As the study deals with imbalance dataset, synthetic minority over-sampling technique is used to resolve the problem. Next, the performance of five classification methods, namely naive Bayes, radial basis function network, support vector machine, logistic regression and random forest, on predicting the survivability are compared. Results show that Random forest outperforms other classifiers.

#### 2 - Automated Surgical Term Clustering Used in Unstructured Surgery Descriptions

Tannaz Khaleghi, Graduate Teaching Assistant, Wayne State University, 4815 4th Street, Suite 1067, Detroit, MI, 48201, United States, Alper E. Murat

Text mining tools provide us a unique opportunity to extract information from textual data. The information therefore can be useful when predicting procedure code and surgery room duration for different surgical cases as text can provide important details about the procedure while other common features might not target them. In this study the goal is to find most informative text feature from unstructured principal procedure and some physician notes by heuristic integrated text mining method which best organize medical text feature set and sets up feature dimensionality reduction efficiently. The output improves surgery code prediction accuracy and produce more reliable surgery duration.



### 3 - Patient - Demographic and Health Factors Influencing the Length of Stay in Hospital

Surya Ayyalasomayajula, Oklahoma State University, Stillwater, OK, 74074, United States, Ankita Srivastava, Dursun Delen

This study explores the question of what are the demographic and general health factors that predict the length of stay (LOS) of a patient in a hospital. It conceptualizes that general health condition has a major impact on the LOS followed by demographics. The paper then studies the hospital factors that influence the average length of stay (ALOS) or Hospital Length of Stay (HLOS). Data from 22 hospitals and 5553 patients strongly support the proposed idea of LOS is determined by general health and demographics. The results do not support the idea that ALOS is dependent on hospital factors.

### 4 - A DEA Evaluation of States' Infant Mortality Rate in the U.S.

Negar Darabi, PhD Student, Virginia Tech, Blacksburg, VA, 24060-4913, United States, Alireza Ebrahimi, Niyousha Hosseinichimeh, Konstantinos P. Triantis

States vary in terms of their infant mortality rates (IMR). Here, we build a state-level database to compare 50 states' performance with respect to three major variables including IMR, preterm birth, and low birth weight. We use a Data Envelopment Analysis (DEA) approach to test different factors associated with high performance in infant survival by benchmarking states. Prior studies, examined IMR of neighboring states rather than using a mathematical model for choosing their peers. DEA finds the best practices for states that suffer from poor outcomes (i.e., high rate of infant mortality). The results of this analysis would be beneficial for policymakers to implement effective interventions.

### 5 - Evaluation of Alternative Diagnostic Test Intervals and Thresholds for Lung Cancer Screening

Mehrad Bastani, Postdoctoral Scholar, Stanford University, 305 Campus Drive, Palo Alto, CA, 94305, United States, Sylvia Plevritis, Iakovos Tournazis, Ann Leung

U.S. Preventive Services Task Force recently recommended a low-dose computed tomography (LDCT) lung screening for high-risk current and former smokers based on the National Lung Screening Trial (NLST). In response to the high rates of false-positive observed in NLST (27.3%), the American College of Radiology developed Lung-RADS, a standardized system for reporting and following-up LDCT findings. Several studies have shown reduction in false-positive rate when Lung-RADS is applied to NLST. To complement these studies, we evaluate the effect of alternative diagnostic testing intervals and actionable nodule size thresholds of Lung-RADS on the mortality reduction associated with LC screening.

## ■ WB64

West Bldg 104A

### Joint Session DM/Practice Curated: Data Science for Decision Support

Sponsored: Data Mining

Sponsored Session

Chair: Kazim Topuz, University of Tulsa, 800 Tucker Ave, Tulsa, OK, 74104, United States

#### 1 - Designing Early Detection and Intervention Techniques via Predictive Models for Bottleneck Business Courses

Sinjini Mitra, Associate Professor, California State University-Fullerton, 800 N. State College Boulevard, ISDS Department, Fullerton, CA, 92831, United States, Zvi Goldstein

We present a study of factors affecting student success in two bottleneck Business courses, and use subsets of them to build predictive models of student success. They can be utilized to detect at-risk students early on for implementing suitable intervention techniques to improve their odds of completing the courses successfully. The results that show that students who receive the intervention and take advantage of it, have significantly improved performance at the end of each course compared to those who do not. We conclude by briefly discussing Supplemental Instruction as an academic support program that benefits such at-risk students greatly.

#### 2 - Should Low Rated Items be Recommended? An Empirical Analysis

Sanjog Ray, Indian Institute of Management-Indore, Rau Pithampur Road, Faculty Block A-202, Indore, 453331, India

Collaborative filtering is the most popular approach used in recommender systems for recommending items like movies, books etc. Items that a user will most likely rate high are recommended as a result low rated items are never recommended. This paper questions the approach of ignoring low rated items by the recommender systems algorithms. Based on our analysis of two large datasets on movies and books, we show that low rated movies should not be ignored in the final list of recommendations. We also provide suggestions on how low rated movies can be recommended.

### 3 - Post-traumatic Stress Disorder (PTSD) Diagnosis & Prediction: A Bayesian Network Model

Yi Tan, University of Kansas School of Business, 1654 Naismith Drive, Lawrence, KS, 66045, United States, Prakash P. Shenoy, Catherine Shenoy, Mary Oehlert

In this study, we first propose a Bayesian network model for post-traumatic stress disorder (PTSD) prediction. By using Veteran Administration patient data between 2000 and 2015, the model is constructed based on patients' demographic information, military history, other accompanied mental disorders, and various psychological tests. Psychological tests are usually required to diagnose/confirm PTSD. To aid the diagnosis, we are also working on a decision support technique that psychiatrists can use to decide which psychological tests, and in what sequence, that a new patient should take. The technique will identify the most informative tests based on information theory.

### 4 - Predicting and Understanding Freshmen Student Retention-Development of a Bayesian Belief Network-based DSS

Kazim Topuz, Assistant Professor, PhD, University of Tulsa, 1826 23rd Avenue SE, Norman, OK, 73071-1065, United States, Dursun Delen

Student attrition is an administratively important, and yet practically challenging problem for decision makers and researchers. This study aims to find the prominent variables and their conditional dependencies/interrelations that effect student attrition in college settings. Specifically, using a large and feature-rich dataset, proposed methodology successfully captures the probabilistic interactions between attrition and related factors to reveal the underlying, nonlinear relationships.

## ■ WB65

West Bldg 104B

### Joint Session DM/Practice Curated: Data Science and Robust Optimization

Sponsored: Data Mining

Sponsored Session

Chair: Hari Bandi, MIT, Cambridge, MA, 02139, United States

#### 1 - Practical Robust Optimization for Least-squares Problems

Long Zhao, UT McCombs Business School, 2110 Speedway Stop B6500, CBA 5.334 Q, Austin, TX, 78712-1277, United States, Deepayan Chakrabarti, Kumar Muthuraman

Solution to Robust optimization formulations is sometimes too conservative because of the worst-case performance objective. For the least-squares problem, we describe a way to overcome this by combining its Robust version with the classical formulation. The talk describes the method and how it leverages on a deeper understanding of estimation errors to help improve out of sample performance. For more than 50 different real-world scenarios, the method consistently outperforms other methods that ignore such space-level information and outperforms both ridge and lasso regression most of the time.

#### 2 - Bootstrap Robust Prescriptive Analytics

Bart Paul Gerard Van Parys, MIT, Room E40-154, 77 Massachusetts Avenue, Cambridge, MA, 02139, United States, Dimitris Bertsimas

We discuss prescribing optimal decisions in a framework where the cost depends on uncertain problem parameters that need to be learned from data. Proper prescriptive methods exploit additional observed contextual information on a large number of covariates. Naive use of training data may lead to gullible decisions over-calibrated to one particular data set. We use robust optimization and the bootstrap to propose two novel prescriptive methods. Both resulting robust prescriptive methods reduce to tractable convex optimization problems and enjoy a limited disappointment on bootstrap data.

#### 3 - Learning a Mixture of Gaussians via Mixed Integer Optimization

Hari Bandi, MIT, Cambridge, MA, 02139, United States

We consider the problem of estimating the parameters of a Gaussian mixture model (GMM) given access to  $n$  samples  $x_1, x_2, \dots, x_n \in \mathbb{R}^d$  that are believed to have come from a mixture of multiple subpopulations. We present here a novel MIO formulation that optimally recovers the parameters of the GMM by minimizing a discrepancy measure between the empirical distribution function and the distribution function of the GMM. We show that the MIO approaches are practically solvable for datasets with  $n$  in the tens of thousands in minutes and achieve an average improvement of 60-70% and 50-60% on MAPE in estimating the means and the covariance matrices, respectively over the EM algorithm independent of the sample size.

■ **WB66**

West Bldg 105A

**Practice- Data Mining in Business Applications I**

Contributed Session

Chair: Amir Hossein Abolhassani, West Virginia University, Dearborn, MI, 48120, United States

**1 - Fatigue Management System for Manufacturing Occupations**

Zahra Sedighi, Auburn University, Auburn, AL, 36830, United States

From a firm's perspective, managing fatigued workers is an important issue with ethical, operational and financial considerations. We propose and delineate a framework for using wearable sensors to manage worker fatigue in manufacturing environments. A framework is proposed instead of a model to allow for the detection/diagnosis of multiple fatigue modes. The proposed framework is made of four phases: (a) detection, (b) identification, (c) diagnosis, and (d) recovery. We present the capability of our proposed framework in two case studies.

**2 - Identifying Long Term Organizational Well Being**

Hamidreza Ahady Dolatsara, Auburn University, 227 Lowder Hall, 405 West Magnolia Ave., Auburn, AL, 36830, United States, Ashish Gupta, David Paradice

This study uses machine learning approaches to understand the concept of long term organizational well-being, i.e., organizational health (OH). A composite OH index is developed based on long term financial performance. Time series of financial indicators are driven from sequential financial data over the past several years. Multivariate time series classification models are then developed for grouping companies into clusters based on their composite OH index.

**3 - How Enterprises Can Emulate Those Better Than Themselves**

Liao Wei-Chih, Doctorial Student, National Chung-Hsing University, Taichung, Taiwan, Lin Chin-Shien, Chang Ruei-Yuan

This paper aims to explore how enterprises can find appropriate strategic learning objects and what they shall pay attention to while choosing such objects. This study fitted the hierarchical linear models to test the hypotheses. The results show that company-level strategic fit has a significant impact on performance and the cross-level group variables and industrial variables have significant moderating effects. Therefore, when choosing a learning object, enterprises must confirm that the homogeneity of the strategic group is enough and understand the content of the ideal configuration. We need to pay more attention to the content of the ideal configuration to obtain better performance.

**4 - Implications of Renegotiation on Testing Time for Software Outsourcing Contract Choice**

Hongyan Xu, Chongqing University, School of Economics &amp; Business Admin, Chongqing, 400030, China, He Huang, Minhui Hu

We examine two commonly used software outsourcing contracts with renegotiation on testing time, i.e., fixed-price and time-and-material contracts, and investigate the impacts of renegotiation on contract choice.

**5 - Preventative Maintenance Forecast for Powertrain Capacity Planning**

Amir Abolhassani, Analytics Scientist, Ford Motor Company, Dearborn, MI, 48120, United States, Rajeev Kalamdani

The current method of estimating planned preventative maintenance consists of adding 10% excess capacity (16.8 hours/week). This method may be over-estimating and leading to over capacity for a required production volume. An algorithm was developed to predict weekly downtime and labor impact of preventative, predictive, and autonomous maintenance based on line configuration and different available operations on seven bill of process (BoPs).

■ **WB67**

West Bldg 105B

**Session on Digital Platforms**

Sponsored: Information Systems

Sponsored Session

Chair: Ni Huang, Arizona State University, Gilbert, AZ, 85233, United States

**1 - Understanding Continuous Citizen Participation in a Green Commuting Platform: The Roles of Public Value and Private Value**

Luning Liu, PhD, Harbin Institute of Technology, Harbin, 150001, China, Jingrui Ju, Yuqiang Feng

E-participation platforms encourage citizens to create public value for public affairs. Prior literature mostly focused on the role of participation in facilitating socially public value creation, with less attention paid to individual private value acquisition. However, the provision of private incentives can promote the production of public goods. Thus, this study develops a model according to theories of citizen participation and incentives to examine what antecedents respectively affect participation in creating public value and acquiring private value and the roles of the two values on continuous participation by using a field survey data.

**2 - Impacts of the Platform-based Sharing Economy on the U.S. Labor Market: Evidence from Uber Entry**

Ziru Li, Arizona State University, Tempe, AZ, United States, Yili Hong, Zhongju Zhang

We study how brand impacts consumer demand in the context of museum memberships in a metropolitan city in the United States. Over the course of our sample, one major museum with a highly recognized brand closed. During the closure, it sequentially co-branded with two established local museums. The closure and co-branding events combined with individual panel data on museum memberships allow us to measure how these changes in brand affect demand. Co-branding with the closed museum lifts demand for the partner museum, however this aggregate increase masks two counter-acting forces. First, customers with no history of buying membership from either museum enter the market, consistent with the prominent brand providing a signal of vertical quality. Second, a sub-group of customers who previously purchased from either or both of the museums display decreased demand. This is consistent with a model of brand providing information about horizontal match value, with decreasing demand from the broadening of brand being an example of brand dilution. The magnitude of these offsetting forces varies between co-branding events. These results have implications for the treatment of brand intercepts in counterfactuals when studying consumer demand.

**3 - Everyone Can Be a Star: Quantifying Grassroots Online Sellers' Live Streaming Effects on Product Sales**

Cheng Chen, University of Illinois at Chicago, Chicago, IL, 60607, United States, Yuheng Hu, Yili Hong, Yingda Lu

The emergence of live streaming services provides online sellers a new channel to sell products. In this paper, we examine the effect of sellers' adoption of live streaming on their online product sales. We found that the adoption of live streaming strategy significantly boosts sellers' online product sales.

**4 - Skill-Biased Technological Change Again? The Impacts of Matching Platforms on Local Labor Markets**

Zhi (Aaron) Cheng, Temple University, Philadelphia, PA, 19130, United States, Xue Guo, Paul Pavlou

Do online matching platforms affect offline labor markets? To answer this question, we exploit a quasi-experiment setting, where a large internet-based matching platform, TaskRabbit, has gradually entered different U.S. cities since 2008. Our difference-in-differences estimation shows that the introduction of TaskRabbit is associated with a decrease in the number of local full-time workers in the traditional housekeeping industry. Moreover, the negative effect is mainly driven by a significant decrease in the number of cognitive routine workers (e.g., first line managers) after the TaskRabbit entry, given a non-significant change in that of manual non-routine workers (e.g., janitors).

**5 - Why Gender Wage Gap does not Necessarily Mean Gender Bias?**

Chen Liang, Arizona State University, Tempe, AZ, United States, Yili Hong, Bin Gu

We explore whether there exists gender wage gap in the gig economy and examine to what degree gender differences in job application strategy could account for the gap. With a large-scale dataset from a leading online labor market, we show that females only earn 81.4% of the hourly wage of males and explore three main aspects of job application strategy, namely, bid timing, choice of jobs based on hourly wage, and avoidance of monitoring. We find that females tend to bid later, prefer jobs with a lower hourly wage budget, and have a higher willingness to pay (WTP) for the avoidance of monitoring. Overall, our study underscores the importance of gender differences in job application strategy on gender wage gap.

## ■ WB68

West Bldg 105C

**Computational Services in Cybermanufacturing Systems**

Sponsored: Quality, Statistics and Reliability

Sponsored Session

Chair: Ran Jin, Virginia Tech, Blacksburg, VA, 24061, United States

Co-Chair: Xiaoyu Chen, Virginia Tech, Blacksburg, VA, 24061, United States

**1 - Statistical Transfer Learning for Profile Monitoring**

Ziyue Li, The Hong Kong University of Science and Technology, Kowloon, Hong Kong, Fuguee Tsung, Ke Zhang

In the practical manufacturing process, there exist quite amounts of similar procedures or stages. When a new task comes, data in new task is too limited to get an accurate parameter estimation. Transfer learning outperforms by joint estimation with Gaussian Graphical Model. Some profiles are observed with sparse anomaly. To deal with it, we propose a new method to capture the relatedness across multiple profiles and detect their anomalies efficiently. Profile is decomposed into smooth background, sparse anomaly and random noise. Smooth background is treated with transfer learning model and group-lasso is introduced for anomaly. Coordinate Descent is adapted to solve the optimization problem.

**2 - A Multitask Learning Based Decomposition Approach for Modeling Distributed Machines**

Hao Yan, Tempe, AZ, 85281, United States, Yifu Li, Ran Jin

Quality prediction is traditionally conducted on the system within a single machine. In this work, we consider the data are collected from multiple machines with different input variables. The machines share similarity but may not be identical. We decompose the variation patterns of multiple machines into explainable variation patterns by input variable, latent variation patterns shared by multiple machines, and noise. Furthermore, we utilize multi-task learning to model the explainable variation patterns. This decomposition can be used for quality prediction and process monitoring. Simulation and case study are conducted to demonstrate the advantage of the proposed algorithm.

**3 - A Physics-specific Change Point Detection Method Using Torque Signals in Pipe Tightening Processes**

Juan Du, Xi Zhang, Jianjun Shi

In pipe tightening processes, the torque signals presents with various quasi-periodic profiles, introducing a bunch of false change points while using existing change point detection methods for condition monitoring. To address this issue, this presentation proposes to consider the profile generating mechanism to improve the detection performance.

**4 - Personalized Recommendation for Information Visualization**

Xiaoyu Chen, Virginia Tech, 302 Heartwood Xing, Blacksburg, VA, 24060, United States, Ran Jin

Information visualization help acquire insights of complex datasets in system engineering. However, a uniform visualization format may be ineffective to bring the insights to different users at different contexts. In this research, a personalized recommendation approach is proposed to dynamically adjust visualization with respect to different tasks and contexts for different users. It can automatically select the significant features from unobtrusive measures to support further diagnostics of the visualization designs.

**5 - Clustering-based Data Filtering for Manufacturing Big Data System**

Yifu Li, Virginia Tech, 302 Heartwood Crossing, Blacksburg, VA, 24061, United States, Xinwei Deng, Ran Jin, Shan Ba, William Myers

As the sensing technology advances in manufacturing, various sensors enable real-time modeling and monitoring of in situ covariates. However, sensors collect massive data, which cause high computational load and excessive data storage in manufacturing. To address these issues, we proposed an unsupervised data filtering method based on index-segmented and clustered datasets. Furthermore, a filtering information criterion is proposed to automatically determine the proportion of data filtered for further data analysis, which effectively balances the trade-off between the sample size of the filtered datasets and information preserved.

## ■ WB69

West Bldg 106A

**Statistical Learning and Modeling of Smart and Connected Systems**

Sponsored: Quality, Statistics and Reliability

Sponsored Session

Chair: Chao Wang, University of Wisconsin-Madison, Madison, WI, 53706, United States

**1 - Cardiac Surface Potential Prediction Based on Gaussian Process and Partial Differential Equation**

Zhiyong Hu, Texas Tech University, 2500 Broadway, Room 240, Lubbock, TX, 79415, United States, Dongping Du

Reconstructing the surface potential in cardiac chambers plays an essential role for precise diagnosis and treatment planning. Gaussian Process (GP) is a popular method that learns the spatial temporal correlations of available data for surface mapping. However, GP kernel functions cannot capture the physiological correlation among cardiac tissue. In this study, we integrate GP with physical models of heart to characterize the covariance structure of surface potential recordings. The resulting model enables an accurate surface prediction, thus providing more insight into cardiac disorders.

**2 - Fault Diagnosis in Multistage Manufacturing Processes Based on Bayesian Linear Random Effects Model with Sparse Variance Components Prior**

Jaesung Lee, University of Wisconsin, 3255, Mechanical Engineering Building, 1513 University Ave, Madison, WI, 53706, United States, Junbo Son, Shiyu Zhou

We present a Bayesian linear random effects model for the fault diagnosis in the multistage manufacturing processes with a prior for the sparse variance components. A modified horseshoe+ prior is used to tackle the low sample size and high dimensional problems with sparse faults. Furthermore, we introduce the informed-horseshoe+ that incorporates the positional fault likelihood information. To estimate the faults from the horseshoe+ prior, Gibbs sampler was developed. In simulation and numerical experiments, the horseshoe+ outperformed the inverse gamma prior in sparse fault cases and the informed-horseshoe+ achieved advantages given additional information on process faults.

**3 - When are Markets out of Control? Monitoring Financial Networks with Online Hurdle Models**

Mostafa Reisi Gahrooei, Georgia Tech, Atlanta, GA, 30318, United States, Samaneh Ebrahimi, Shawn Mankad, Kamran Paynabar

The interconnectedness of financial institutions can function as a mechanism for the propagation and amplification of shocks throughout the economy, thus contributing to financial crises. As such, network analysis has become a critical tool to assess interconnectedness and systemic risk levels. In this paper we create a formal monitoring system to detect changes within a sequence of sparse networks constructed from an interbank lending market in the European Union.

**4 - Transfer Learning of Structures of Ordered Block Graphical Models Using Informative Priors**

Chao Wang, University of Wisconsin Madison, Rm. 3255, ME building 1513 University Ave., Madison, WI, 53706, United States, Shiyu Zhou

We focus on the structure learning of ordered block model (OBM) based on data-driven informative prior. A novel informative structure prior distribution is represented by a categorical random variable. In this way, the informative prior distribution construction is equivalent to the parameter estimation of the graph random variable distribution using historical data. The sample space inconsistency between historical and new OBMs is addressed by adding pseudo nodes with probability normalization, then removing extra nodes through marginalization. The simulation and real case study show the effectiveness of the proposed method, especially when the data from the new OBM is small.



## ■ WB70

West Bldg 106B

### Reliability II

Contributed Session

Chair: Oluseye Fafiolu, Lamar University, Beaumont, TX, Texas, United States

#### 1 - Statistical Inference on Remaining Useful Life in a Two-phase Degradation Model Under Gamma Process

Hon Keung Tony Ng, Professor, Southern Methodist University, 3225 Daniel Avenue, Department of Statistical Science, Dallas, TX, 75275-0332, United States, Man Ho Ling, Kwok-Leung Tsui

Due to physical and chemical changes that take place with usage and with age, a significant degradation rate change of a product usually exists. To accurately predict the remaining useful life prediction for products with two-phase degradation, we incorporate a probability distribution of the time of rate change into the gamma degradation model. A Bayesian approach and a frequentist approach are proposed for statistical inference of the remaining useful life. A simulation study is used to evaluate the performance of the developed methodologies and a real data set on light emitting diodes is presented to illustrate the application of the proposed model.

#### 2 - Condition-based Maintenance and Production for Systems with Overcapacity

Michiel uit het Broek, MSc, University of Groningen, Groningen, Netherlands, Ruud Teunter, Bram de Jonge, Jasper Veldman

Many multi-unit systems face significant economic dependencies for performing maintenance, e.g., expensive vessels are needed to perform maintenance at offshore wind farms. Therefore, it is often cost efficient to cluster maintenance for several units in the system. However, when maintenance for units with different degradations levels is clustered, then maintenance is performed too early for the low deteriorated ones or too late for the highly deteriorated ones. In such situations, an interesting question is whether it can be profitable to adjust the production rates in order to synchronize the deterioration processes for the different units.

#### 3 - Joint Optimization of Job Scheduling and Condition-based Maintenance

Bram de Jonge, University of Groningen, P.O. Box 800, Groningen, 9700 AV, Netherlands

We consider a production facility that processes incoming jobs of various lengths and that requires maintenance due to deterioration and ultimately failure. We present an approach to determine whether the system has a steady state. Based on maintenance costs and total weighted flow time costs we formulate a Markov decision process to determine optimal maintenance and job scheduling policies. We provide insights on how job scheduling and maintenance planning interact.

#### 4 - Physics-of-failure Based Reliability Prediction Model for Rail Track Geometry

Oluseye Fafiolu, Lamar University, 4400 Mlk Pkwy, Beaumont, TX, 77701, United States, Jaeyoung Cho, Maryam Hamidi

We propose a rail track geometry reliability prediction model based on physics-of-failure approach. The failure mechanisms that causes rail track geometry degradation are incorporated into the model. We expect that the reliability model predicts accurately the optimum working hours under normal operating conditions of the rail track geometry prior to maintenance actions being required.

## ■ WB71

West Bldg 106C

### Advances in Computational Optimization

Sponsored: Computing

Sponsored Session

Chair: John W Chinneck, Carleton University, Ottawa, ON, K1S 5B6, Canada

#### 1 - Linear Programming Based Sparse Solutions Revisited

John W. Chinneck, Carleton University, Systems and Computer Engineering, 1125 Colonel By Drive, Ottawa, ON, K1S 5B6, Canada

Finding sparse solutions for underdetermined linear systems is the key step in compressive sensing and a number of other important problems. One category of solutions uses linear programming, e.g. Basis Pursuit. However there are other ways to formulate the LP which have not been explored and which lead to different algorithms with different characteristics. The talk presents a variety of new LP-based formulations and associated algorithms, along with numerical evaluation and comparisons.

#### 2 - Optimization Modeling in Matlab

Aurele Turnes, MathWorks, Natick, MA, 01760, United States, Steve Grikschat, Paul Kerr-Delworth, Adam Hug

The problem-based workflow for optimization has made it much easier to model and solve an optimization problem in MATLAB. First, optimization variables are identified and defined. They can be N dimensional and can be indexed similar to standard MATLAB arrays. Next, familiar MATLAB operators can be used to define the objective and constraints as expressions of the optimization variables. Finally, the optimization solver is automatically selected based on the type of objective and constraints. Large and complex optimization problems expressed in this way are more compact and readable. We will review the problem-based workflow and demonstrate new capabilities with examples.

#### 3 - Constraint-based Sequential Pattern Mining Using Multi-valued Decision Diagrams

Amin Hosseininasab, Tepper School of Business, Carnegie Mellon University, 5000 Forbes Avenue, Pittsburgh, PA, 15213, United States, Willem van Hoeve, Andre Augusto Cire

Constraint-based sequential pattern mining (SPM) has gained recent attention as it aims to find patterns interesting to the user, rather than an arbitrary set of frequent patterns. We propose a general framework for imposing non-monotone constraints into SPM. Such constraints impose restrictions on different item attributes, and are challenging or impossible for current mining algorithms. We use multi-valued decision diagrams to compactly model the database, and use it to store critical information required to impose all constraints. We compare our algorithm to specialized SPM algorithms in the literature, and present a number of novel insights from a real-world database.

## ■ WB72

West Bldg 211A

### Practice- Operations Management III

Contributed Session

Chair: Yiwei Huang, Pennsylvania State University, Mars, PA, 16046, United States

#### 1 - Impact of Shorttermism on Capacity Investment in Competitive Markets

Xiaoyan Liu, PhD Student, Cornell University, Sage Hall, Ithaca, NY, 14853, United States, William Schmidt

We study how a firm's short-term interest in its capital market valuation will affect its capacity decision and long-term profits in the presence of a competitive entrant. We show that the firm with private demand information prefers to signal a high (low) demand when short-termism is high (low). Moreover, pooling equilibria can occur with either low or high levels of short-termism, and both firm types will under-invest in a pooling outcome when short-termism is sufficiently low. We find that the impact of short-termism on long-term profits changes with the firm type and the equilibrium type.

#### 2 - A Wholesale Supply Contract with a Secondary Price Commitment

Ayhan Aydin, George Mason University School of Business, 4400 University Drive, MS 5F4, Fairfax, VA, 22030, United States, John R. Birge, Izak Duenyas

In procurement from low-cost but less flexible supply options, especially of products with highly variable demand and of seasonal nature, advanced auctions and non-linear compensation schedules can be used to correct inefficiencies due to double marginalization, information asymmetry, and demand uncertainty. We introduce an alternative simple-to-administer contracting scheme that requires minimal effort to implement, which can be used especially when the suppliers do not offer revenue sharing, buy-back, or real option contracts. We study how it allows the buyer to benefit further from low-cost distant supply options. We show that a truly low-cost supplier can also benefit from such a scheme.

#### 3 - Quality Control Strategies in Two-sided Market

Lyu Gaoyan, Peking University, No.5 Yiheyuan Street, Beijing, 100871, China, Lihua Chen

Consumers focus on product quality increasingly. We design two quality control strategies to help two-sided platform improve its product quality. Using Stankburg method, we compare the optimal profits with two quality control methods. The result shows that taking any strategy is better than taking no action. Moreover, taking both strategies will bring higher social welfare.

**4 - A Framework for Analyzing the U. S. Coin Supply Chain**

Yiwei Huang, Assistant Professor, Pennsylvania State University - Shenango, 173 Broadstone Drive, Mars, PA, 16046, United States, Subodha Kumar, Bala Shetty, Chelliah Sriskandarajah, Yunxia Zhu

We analyze the supply side of the U.S. Coin Supply Chain with the objective of providing a near-optimal or an optimal operating policy that minimizes the total cost of producing, supplying, and managing coin inventory in the U.S. Coin Supply Chain. We develop efficient algorithms to solve various versions of the coin-management problem and perform an extensive analysis to answer several managerially relevant questions in the context of improving the efficiency of the U.S. Coin Supply Chain.

**WB73**

West Bldg 211B

**Practice- Optimization II**

Contributed Session

Chair: Elham Taghizadeh, Wayne State University, Detroit, MI, 48035, United States

**1 - Exact Penalization for Generalized Nash Equilibrium Problem**

Qin Ba, University of Southern California, Los Angeles, CA, United States, Jong-Shi Pang

The Generalized Nash Equilibrium Problem (GNEP) extends the classical Nash Equilibrium Problem (NEP) by allowing individual players' constraints, in addition to objectives, to depend on rivals' decisions. It is an important model actively used in many different fields. However, solution algorithms are extremely scarce due to the presence of coupling constraints. This paper studies penalty methods which penalize violation of individual players' coupling constraints and transform a GNEP into a single NEP. Several sufficient conditions are provided which guarantee exact penalization, i.e., the penalized NEP has identical solution sets as the original GNEP for finite penalty parameter.

**2 - Underestimate Sequences via Quadratic Averaging**

Chenxin Ma, JD.com, Mountain View, CA, United States, Naga Venkata C. Gudapati, Majid Jahani, Rachael Tappenden, Martin Takác

In this work we introduce the concept of an Underestimate Sequence. Our definition of a UES utilizes three sequences, one of which is a lower bound (or under-estimator) of the objective function. We propose several first order methods for minimizing strongly convex functions in both the smooth and composite cases. The algorithm have natural stopping conditions, which provides the user with a certificate of optimality. Convergence of all algorithms is guaranteed through the UES framework, and we show that all presented algorithms converge linearly, with the accelerated variants enjoying the optimal linear rate of convergence.

**3 - Optimizing Schedule of Trains in Context of a Large Railway Network**

Srinivasa Prasanna, IIIT Bangalore, 26/C, Hosur Road, Electronics City, Opposite Infosys Technologies, Bangalore, 560100, India, Sanat Ramesh, Tarun Dutt, Anushka Chandrababu, Abhilasha Aswal

We present two heuristics based on MILP formulations to optimize utilization for train timetabling problems for portions of one of the largest railway networks. These methods (extending state-of-art solvers) provide flexibility in scheduling additional trains while respecting a large number of constraints. We present methods to validate the deterministic schedule over global correlated variations in travel times without making any probabilistic assumptions.

**4 - A Branch and Bound Algorithm for Two-machine No-wait Flow Shop Scheduling with Truncated Learning Function**

Vahid Azizi, Iowa State University, Ames, IA, United States, Guiping Hu

There have been increasing interests in production scheduling considering learning effects. However, this problem has not been studied in a no-wait flow shop scheduling setting. This paper addresses a two-machine no-wait flow shop with the effect of the truncated learning function. With the truncated learning function, processing times of the jobs depend on their positions in the sequence and the learning parameter. A branch and bound algorithm is designed to minimize the makespan. A lower bound and two dominance properties are proposed which increase computational efficiency for the branch and bound algorithm.

**5 - Global Non-probabilistic Validation of Schedules**

GN Srinivasa Prasanna, International Institute of Information Technology Bangalore (IIITB), Bengaluru, 560100, India, Anushka Chandrababu, Abhilasha Aswal, Sanat R, Tarun Dutt

Deterministic optimization problems for train timetabling over even small portions of one of the world's largest railway networks become intractable when uncertainty is introduced. We present methods based on linear programming to validate nominal schedules over global correlated variations in travel times (satisfying linear constraints) without making any probabilistic assumptions.

**6 - A Hybrid Bat Algorithm for a Risk Averse Two Stage Stochastic Replenishment Problem with Transportation Costs**

Elham Taghizadeh, Wayne State University, Detroit, MI, 48202, United States, Saravanan Venkatachalam, Ratna Babu Chinnam

Integrating inventory and transportation decisions can provide significant gains in the supply chain management. In this talk, we present a two-stage risk-averse stochastic programming model with Conditional-Value-at-Risk (CVaR) as risk-measure for a multi-item replenishment problem with transportation cost and demand uncertainty. To circumvent computational complexity, we develop a Hybrid Bat algorithm to solve the large-scale instances. Computational results based on sample average approximation approach will be presented.

**WB75**

West Bldg 212B

**Stakeholder Analysis**

Sponsored: Military and Security

Sponsored Session

Chair: Randy K. Buchanan, USACE - ERDC, Vicksburg, MS, 39180, United States

Co-Chair: Simon Goerger

**1 - Using Data Analytics on Stakeholder Requirements Data to Inform Research Innovation**

Christina Rinaudo, USACE Engineer Research and Development Center, 3909 Halls Ferry Road, Vicksburg, MS, 39180-6199, United States, Niki C. Goerger, Simon Goerger

A recent stakeholder workshop to identify and discover challenges generated an initial data set of potential stakeholder requirements. Leveraging text and data analysis tools such as Tableau and R to analyze the stakeholder requirements data, areas for R&D efforts are illuminated to inform research innovation.

**2 - Developing an Analytical Tool to Assess Stakeholder Engagements**

Janice P. Buchanan, USACE - ERDC, 3909 Halls Ferry Road, Vicksburg, MS, 39180, United States, Randy K. Buchanan, Simon Goerger, John R. Burt

Identifying key stakeholders and tracking meeting results for a complex organization can be a daunting task. This presentation reviews the methodologies behind and development of StEAM - Stakeholder Engagement and Assessment Tool. StEAM is a prototype tool developed and used by the US Army Research and Development Center to help schedule stakeholder meetings, identify goals, and record accomplishments of senior leader engagements.

**3 - Shared Vision Planning for Water Security – A Stakeholder Analysis Framework**

James Schreiner, U.S. Military Academy-West Point, Dept. of Systems Eng, Room 420, Mahan Hall, West Point, NY, 10996, United States

Regional and Global water security represents an increasing risk and can be negatively or positively impacted by quality decisions of water management and infrastructure investment. Balancing watershed attributes of water storage, hydropower yield, risk mitigation, crop yield, and navigation among others becomes a difficult proposition when multi-national stakeholders are involved. This presentation will present a framework developed to use visual tools to capture stakeholder needs, wants, and desires while creating a shared situational awareness of the watershed system. The Tigris-Euphrates watershed provide the case study for this work.

## ■ WB76

West Bldg 212C

### Navigating the Funding Landscape

Sponsored: Minority Issues

Sponsored Session

Chair: Trilce Encarnacion, Rensselaer Polytechnic Institute, Troy, NY, 12180, United States

#### 1 - Navigating the Funding Landscape

Trilce Encarnacion, Rensselaer Polytechnic Institute, Troy, NY, 12180, United States

This panel will explore a variety of opportunities for funding your ORMS research. Lessons learned and best practices to increase your funding success will be shared.

#### Panelist

Jennifer A. Pazour, Rensselaer Polytechnic Institute, Troy, NY, 12180, United States

## ■ WB77

West Bldg 213A

### Nonprofit Operations Management

Sponsored: Public Sector OR

Sponsored Session

Chair: Gemma Berenguer Falguera, Purdue University, Purdue, West Lafayette, IN, United States

#### 1 - Performance Metrics for Emergency Response Network Design

Alexander Rothkopf, Massachusetts Institute of Technology, Cambridge, MA, 65197, United States, Jason Acimovic, Jarrod D. Goentzel

We use a stochastic linear program to model a US-based emergency response organization's network of warehouses to serve sudden onset disasters. We develop multiple performance measures to characterize the risk portfolio, the supply portfolio and the carrier portfolio to support decision-makers in evaluating the status-quo of their operations and suggest areas of improvement. We show how our model and the measures work with data from our case.

#### 2 - Supply Constrained Location-distribution in Nonprofit Settings

Gemma Berenguer, Purdue University, West Lafayette, IN, 47906, United States, Chong Park

There is a need to design location-distribution problems in not-for-profit settings where limited resources have to be allocated to different demand regions and, thus, a combination of efficiency and equity goals can rightfully be considered. In this paper, we design and solve models that represent this setting. In particular, we propose the use of a well-known fractional efficiency measure and a new inequity measure related to the Gini coefficient that is based on the relative utility obtained by each demand region given a certain supply allocation. Our resolution technique allows us to use fractional objective measures that have not been commonly utilized before due to tractability issues.

#### 3 - Value of Combining Patient and Provider Incentives in Humanitarian Healthcare Service Programs

Karthik Natarajan, University of Minnesota, Minneapolis, MN, 55455, United States, Mili Mehrotra

We analyze the incentive design problem faced by a budget-constrained humanitarian organization managing a healthcare delivery program. Incentives offered to the healthcare provider are aimed at improving the quality and quantity of services offered, and demand-side incentives are used to encourage patients to seek care. In practice, incentives are often targeted at improving the availability of healthcare services. However, our results suggest that by offering the right combination of incentives to the provider and patients, program performance can be improved significantly. Furthermore, using the right incentives is critical to fully realizing the benefits of fundraising efforts.

#### 4 - Donor Funding for Drug Availability

Iva P. Rashkova, Washington University in St Louis, St Louis, MO, United States

Motivated by the Global Fund grant recipients, we study the procurement of health products subject to a donor budget constraint. Donor funding is in the form of lump-sum disbursements or per-unit subsidy agreements, or both. The donor objective is to maximize consumption in the face of demand uncertainty and grant recipients' unobservable procurement costs. We derive the optimal allocation of donor funds, which exhibits a risk-hedging synergy between the two types of funding. Using Global Fund data, we find that implementing the optimal budget allocation includes both types of funding for 60% of grant recipients and could lead to up to 21% increase in total consumption.

## ■ WB78

West Bldg 213B

### Joint Session PSOR/TSL Urban: Sustainable Transportation/Logistics in Public Sector OR I

Sponsored: Public Sector OR

Sponsored Session

Chair: Sung Hoon Chung, Binghamton University, Binghamton, NY, 13902, United States

#### 1 - Setting up a Liquefied Natural Gas Refueling Infrastructure and Greenhouse Gas Emissions Savings on the Pennsylvania Turnpike

Sang Jin Kweon, Carnegie Mellon University, Pittsburgh, PA, 15213, United States

Recognizing the increased spotlight on liquefied natural gas (LNG) for long-haul fleets, logistics companies are interested in switching their long-haul fleets from diesel to LNG. In this talk, we present a bi-criteria binary linear programming model to locate LNG refueling stations on a directed transportation network with two conflicting objectives; maximizing the annual total vehicle-miles traveled covered by the stations and minimizing the capital cost for building the refueling infrastructure. We applied the proposed model to the Pennsylvania (PA) Turnpike System and estimate the potential reduction of pollutants on the turnpike as a function of the LNG refueling infrastructure cost.

#### 2 - Automated Guideway Transit (AGT) System Control Design with Q-learning Algorithm

Young Jae Jang, KAIST, Daejeon, Korea, Republic of, Ilhweo Hwang

The automated guideway transit (AGT) is a class of transportation system consisting of automated vehicles operating on a network of guideways or specially designed rails. This system is also known as Personal Rapid Transit (PRT) or pod-cars. One of the challenges in commercializing the AGT is the development of a routing algorithm controlling massive number of vehicles. We introduce AI based algorithm, Q-learning routing, which effectively control AGT system which consists of massive number of vehicles. Simulation analyses validate that the proposed algorithm outperforms the conventional DP based algorithms in terms of transit service times.

#### 3 - A Hybrid Heuristic Method for the Zero Emission Vehicles (ZEV) Routing Problem with Fueling Stations

Shichun Hu, University of Southern California, Los Angeles, CA, United States

Recent researches on Vehicle Routing Problem (VRP) have included the effect of greenhouse gas emissions to help alleviate the global climate change. One direction is to incorporate ZEVs into VRP models. Despite their advantages of zero or near-zero emissions, the fact that ZEVs have less mile range per fueling and less fueling stations is likely to offset their benefits thus making it harder to replace diesel trucks. We propose a method that combines Adaptive Large Neighborhood Search with local search to solve the ZEV routing problem considering fueling stations.

#### 4 - Optimal Location Design and Dynamic Pricing of Electric Vehicle Charging Facilities under Uncertain Demand and User Decisions

Leila Hajibabai, Stony Brook University, Department of Civil Engineering, 2433 Computer Science, Stony Brook, NY, 11794, United States, Amir Mirheli

This study develops a methodology that incorporates a dynamic pricing scheme into facility location design for electric vehicle charging infrastructure. The objective is to determine the optimal location and capacity of charging facilities in the transportation network and the optimal pricing based on demand. The problem is formulated as a bi-level optimization program that minimizes the total costs including infrastructure investments and operation costs of facilities under user-equilibrium flows. Numerical experiments confirm that the proposed methodology solves the problem efficiently.



## Wednesday, 1:30PM - 3:00PM

### ■ WC01

North Bldg 121A

#### Interpretable Machine Learning via Optimization

Sponsored: Optimization/Optimization under Uncertainty

Sponsored Session

Chair: Dimitris Bertsimas, Massachusetts Institute of Technology, Cambridge, MA, 02139, United States

##### 1 - Optimal Prescriptive Trees

Jack Dunn, Massachusetts Institute of Technology, Cambridge, MA, United States, Dimitris Bertsimas, Nishanth Mundru

Most machine learning approaches focus on predictive tasks, but in reality the final goal is actually to make optimal decisions. We present Optimal Prescriptive Trees (OPT), an interpretable approach for making personalized treatment prescriptions that learns from observational data. While constructing the tree, our method simultaneously infers the unknown counterfactuals in the data and learns to make optimal prescriptions, resulting in a decision tree that optimizes both the predictive and prescriptive error. OPT is interpretable, highly scalable, handles multiple treatments, and performs competitively with several state of the art methods.

##### 2 - Optimal Online Impute

Daisy Ying Zhuo, Massachusetts Institute of Technology, Cambridge, MA, United States, Dimitris Bertsimas, Colin F. Pawlowski

Missing data is a common problem in real-world settings and has attracted significant attention in the statistical literature. We have proposed a flexible framework based on formal optimization to impute missing data that readily incorporate various predictive models including K-nearest neighbors, support vector machines, and decision tree based methods. More recently, building on this framework, we have developed a fast and accurate method to impute data in an online fashion, where observations with potential missing data are provided one at a time. In large-scale experiments with real-world data and a range of learning tasks, we demonstrate improved accuracy using this approach.

##### 3 - Optimal Nonlinear Trees

Yuchen Wang, Massachusetts Institute of Technology, Dimitris Bertsimas, Jack W. Dunn

MARS is a greedy method for constructing a decision tree with nonlinear prediction functions in the leaves. We show that we can formulate the process of building such trees as a global optimization problem, which gives rise to our new method, Optimal Nonlinear Trees. We show in a collection of synthetic and real-world datasets that our Optimal Nonlinear Trees improve substantially over MARS, and also perform better than tree-based boosting methods like xgboost on most small to medium size datasets.

##### 4 - Nonparametric Prescriptive Analytics with Continuous, Constrained Decisions

Nishanth Mundru, Massachusetts Institute of Technology, Dimitris Bertsimas

Most real world business analytics problems involve solving optimization problems that depend on uncertain parameters  $Y$ . Given historical data on uncertainties  $Y$  and observed covariates  $X$ , we consider the problem of prescribing optimal data driven decisions. Our work adapts nonparametric methods such as k-nearest neighbors, local kernel regression, trees, and random forests to learn from data in a single step and produce high quality decisions. We demonstrate the effectiveness of our methods by applying them on various problems.

### ■ WC02

North Bldg 121B

#### Joint Session OPT-Uncert/APS: Optimization in Statistics I

Sponsored: Optimization/Optimization under Uncertainty

Sponsored Session

Chair: Robert Bassett, Naval Postgraduate School, Monterey, CA, United States

##### 1 - Robust Policy Improvement under Residual Confounding

Angela Zhou, Cornell University ORIE, 206 Rhodes Hall, Ithaca, NY, 14853, United States, Nathan Kallus

We study the problem of learning personalized decision policies from observational data which are robust in view of possible confounding. Unlike previous approaches for policy learning which assume unconfoundedness, that there are no unobserved confounders jointly affecting treatment assignment as

well as outcome response, our framework for robust policy improvement optimizes the minimax regret of a candidate policy against the standard of care, generalizing inverse-propensity weighted estimators. We demonstrate our methods can achieve beneficial out-of-sample performance on synthetic data and construct an evaluation study from a large clinical trial.

##### 2 - Statistics with Set-valued Functions: Applications to Inverse Approximation Optimization

Anil Aswani, UC Berkeley, San Francisco, CA, 94103, United States

Much statistical theory does not directly translate to sets because they do not form a vector space. Building on probability theory for random sets, this paper uses variational analysis to develop operational tools for statistics with set-valued functions. These tools are first applied to kernel regression of set-valued functions. The second application is to the problem of inverse approximate optimization, in which approximate solutions (corrupted by noise) to an optimization problem are observed and then used to estimate the amount of suboptimality of the solutions and the parameters of the optimization problem that generated the solutions.

##### 3 - Detecting Communities in Relational Event Data with Non-negative Tensor Decomposition

Xiaoyue Li, University of California-Davis, Davis, CA, United States

A point-to-point process models timestamped interactions between two entities in their state spaces. This study looked into the NYC Taxi dataset, where there were interactions of taxi trips between locations with their timestamps being the pick-up times. Assuming the temporal pattern of taxi trip intensities can be determined by community labels of pick-up and drop-offs, like neighborhoods, airports and tourist locations, the intensity estimation naturally requires detecting this community structure. To this end, we applied point-to-point models and developed a multiplicative update algorithm to estimate the intensity with a non-negative low-rank tensor reconstruction of the dynamic network.

##### 4 - A Semidefinite Programming-based Kernel Clustering Algorithm for Gaussian Mixture Models in the Presence of Outliers

Prateek Raj Srivastava, University of Texas at Austin, Austin, TX, 78712, United States, Purnamrita Sarkar, Grani Adiweni Hanasusanto

We consider the problem of clustering data points generated from a mixture of Gaussians in the presence of outliers. We propose a semidefinite programming-based algorithm that takes as input a kernel distance matrix to first denoise the original data, followed by spectral clustering to recover the true cluster labels of data points. Using Grothendieck's inequality, we obtain theoretical guarantees on the error rates. Further, we compare the performance of our algorithm with other existing algorithms like k-means++ and vanilla spectral clustering.

### ■ WC03

North Bldg 121C

#### Practice- Modeling and Optimization for Decision Making II

Contributed Session

Chair: Michele J. Fisher, Northwestern University, Regina, SK, S4S 2H7, Canada

##### 1 - MCDA with Little or No Data

Lawrence D. Phillips, Emeritus Professor, London School of Economics & Political Science, London, NW3 1AH, United Kingdom

Unique decisions involving multiple criteria are often characterised by conflicting or sparse data, or even no data, so we rely on expert judgment. In this talk I explain and illustrate seven best-practice principles, with evidence they lead to reliable and valid results. The principles include impartially facilitating decision conferences of diverse experts, engaging experts' mental models, gaining clarity about the decision context, developing good definitions of criteria, applying proper scoring and weighting techniques, checking consistency, and conducting extensive sensitivity analyses.

##### 2 - Optimization and Scheduling Methodologies to Enable Low Earth Orbit Nano-satellite Communication

Michelle L. Song, University of Washington, Seattle, WA, 98105, United States, Cherry Yu Wakayama, Zelda B. Zabinsky

Communications with low earth orbit nano-satellites (nanosats) are challenging due to short contact time intervals and uncertainty in successful delivery of messages. We present optimization models (with and without energy constraints) to enable timely delivery of messages between gateways and remote users via nanosats. Connections between nanosats and remote users may not be well established; the uncertainty is modeled using a chance constraint. A network flow program is formulated to optimize the scheduling/routing of messages. Decisions are chosen to minimize the delivery time. Although the decisions are binary variables, the models are shown to satisfy the integrality property.

### 3 - An Application of Doubly Stochastic Nonhomogeneous Poisson Process for Detecting Abnormalities

Joonho Bae, Korea Advanced Institute of Science and Technology, 291, Daehak-ro, Yuseong-gu, Daejeon, Korea, Republic of, Seung-hoon Lee, Woojin Cho, Jinkyoo Park

The anomaly detection problem can be considered with a stochastic counting process. The event of interest is firstly defined as an exceedance of a numerical threshold of the data. Log Gaussian Cox Process, a doubly stochastic nonhomogeneous Poisson process is used to fit the occurrence pattern of the events. The probability value for the data realization within a fixed time interval under the trained intensity function, as a normality score, is calculated and checked if it is below a pre-determined criterion, which is regarded as an anomaly. The robustness of the model is also verified for the abrupt change within the data.

### 4 - Using Analytics to Improve Patron Engagement at the Los Angeles Philharmonic

Michele J. Fisher, Northwestern University, Chicago, IL, United States, Shelley de Leon, Erin Po, Scott Kennedy

One hundred years ago, the Los Angeles Philharmonic was founded as L.A.'s first permanent symphony orchestra. A century later, the LA Phil is one of the most dynamic music organizations in the world. It combines a commitment to the future with a fresh eye on the past. The Phil has been using analytics of historical giving data to target future fundraising efforts. Our team analyzed demographics, ticketing, and giving history for patrons and built models to predict the likelihood of a donation and the associated amount. This is helping the organization get ready for the next century.

## WC04

North Bldg 122A

### Combinatorial Optimization

Sponsored: Optimization/Integer and Discrete Optimization  
Sponsored Session

Chair: Rajan Harish Udawani, Massachusetts Institute of Technology, Cambridge, MA, 02139, United States

#### 1 - Continuous Submodular Maximization and Applications

Rad Niazadeh, Postdoctoral Researcher, Stanford University, 353 Serra Mall, Gate BLDG, Office 484, Stanford, CA, 94305, United States, Tim Roughgarden, Joshua Wang

Submodular optimization has deep roots in various application domains such as machine learning, finance, biology, auctions, or even statistical physics. In this work, we consider the natural generalization of submodularity to continuous domains, termed as Diminishing Return submodularity (DR-SM). We design algorithms with tight approximation guarantees for maximizing such functions over the unit hypercube. We show there exists an algorithm achieving at least  $1/2$  of the value of the optimal point (tight under standard complexity theoretic assumptions). For the special case of strong DR-SM, i.e. with additional coordinate-wise concavity, we develop a fast binary search  $1/2$ -approximation.

#### 2 - Approximating Maximin Fair Allocations

Peter McGlaughlin, University of Illinois Urbana Champaign, Urbana, IL, United States

We study the fair division of indivisible goods between agents with additive valuations. We use the recently introduced maximin share as local measure of fairness of an allocation. A maximin share is the maximum value an agent can guarantee himself if he is allowed to partition the goods into  $N$  bundles (one for each agent), but is allocated his least preferred bundle. We give a simple, greedy algorithm which provides a  $2/3$  maximin share allocation, i.e., an allocation where each agent receives a bundle worth at least  $2/3$  of their maximin share.

#### 3 - Robust Appointment Scheduling

Rajan Udawani, MIT, Cambridge, MA, United States, Andreas S. Schulz

Designing simple appointment systems that try to achieve both high utilization of expensive medical equipment and personnel, and short waiting time for patients, has long been an interesting problem in healthcare. In this work we consider a robust version of the appointment scheduling problem, and give a simple heuristic that achieves the first constant factor approximation. We also show optimal solutions in various special cases that supersede previous work. For the case where order of patients is interchangeable, and under-utilization costs are homogeneous, we show a simple ratio based heuristic that achieves a  $1.06$  approximation, improving the  $2+\epsilon$  approximation in Mittal et al. (2014).

## WC05

North Bldg 122B

### Recent Software Developments and Benchmarks

Sponsored: Optimization/Computational Optimization and Software  
Sponsored Session

Chair: Hans Mittelmann, Arizona State University, Tempe, AZ, 85287-1804, United States

#### 1 - Latest Benchmark Results

Hans Mittelmann, Arizona State University, Tempe, AZ, United States

We report on the current status of our benchmarking effort for both discrete and continuous, commercial and noncommercial optimization software.

#### 2 - Recent Enhancements to Matlab Optimization Solvers

Mary C. Fenelon, MathWorks, 3 Apple Hill Dr., Natick, MA, 01760-2098, United States

MATLAB has solvers for linear, quadratic, nonlinear, and mixed-integer linear optimization problems. They can solve both analytical and black-box models, including those with multiple objectives. Recent enhancements to these solvers and guidance on selecting a solver will be presented.

#### 3 - Gurobi 8.0 - What's New

Zonghao Gu, Gurobi Optimization, 3733-1 Westheimer Rd Box 1001, Houston, TX, 77027, United States

We will give an overview on new features and improvements in the current Gurobi release. In particular, we focus on the new Cloud and Compute Server enhancements and present our newest performance improvements.

#### 4 - CPLEX Progress in 2018

Andrea Tramontani, IBM Italy, Bologna, 06600, Italy, Xavier Nodet

In this talk, we will present the new features in the upcoming CPLEX version, as well as some of the performance improvements that were obtained.

## WC06

North Bldg 122C

### Global Optimization I

Sponsored: Optimization/Global Optimization  
Sponsored Session

Chair: Logan Michael Mathesen, Arizona State University, 699 S. Mill Ave, Tempe, AZ, 85281, United States

#### 1 - High Dimensional Global Optimization via Optimization of Complimentary Communicating Low Dimensional Subspaces

Logan Michael Mathesen, Arizona State University, 699 S. Mill Ave, Tempe, AZ, 85281, United States, xinsheng li, Kasim Seluck Candan, Giulia Pedrielli

Global optimization suffers the curse of dimensionality. High dimensional search is dominated by the assumption of low effective dimensionality, where few dimensions impact function value, with sophisticated algorithms searching for and exploiting a projection, or creating random embeddings. We avoid assuming low effective dimensionality and high dimensional modeling by optimizing sets of complimentary subspaces (that collectively exhaust the full space). Enabling intelligent information sharing amongst subspace optimizations, guiding one another to new optimal global projection locations.

#### 2 - Trans-dimensional Seismic Inversion by the Hamiltonian Approach

Sen Mrinal, Professor, University of Texas at Austin, 10100 Burnet Road, PRC, Bld 196, Austin, TX, 78758, United States, Reetam Biswas

Seismic reflection data are used for characterization of hydrocarbon reservoirs. We have developed a trans-dimension full waveform inversion technique in which the number of subsurface parameters is also treated as a variable to be solved for. The problem is set up in a Bayesian framework which draws samples from the posterior probability distribution. We make use of the sensitivity information to take large jumps in our model search using the Hamiltonian framework and thus we are able to draw several models from the most significant parts of the posterior distribution quickly. These are then used to estimate uncertainty which can be further used in decision making.

### 3 - Combining Exact Global Optimization and Nature-inspired Meta-heuristics: Revealing Robust Black-box Optimization Problem Solving Characteristics

Logan Mathesen, Research Assistant, Arizona State University, 699 S. Mill Ave, Tempe, AZ, 85281, United States, Giulia Pedrielli

Stochastic Optimization with Adaptive Restart (SOAR), recently proposed by the authors, mixes local and global search through controlled restarts. Despite good empirical performance SOAR is difficult to effectively parallelize. In this work we treat SOAR as an agent, parallelizing, we mix explorative (L vy) agents with exploitative SOAR agents. Meta-models blend information of each agent type, improving SOAR agent search. The distributed SOAR (dSOAR) algorithm results; experimentation investigates relationships between agent types, revealing robust cost effective dSOAR optimization behavior.

## ■ WC08

North Bldg 124A

### Stochastic Optimization Methods and Approximation Theory in Machine Learning II

Sponsored: Optimization/Nonlinear Programming

Sponsored Session

Chair: Aritra Dutta, Thuwal, 23955-6900, Saudi Arabia

Chair: El houcine Bergou, INRA-KAUST, Jeddah, Saudi Arabia

#### 1 - Random Direct Search Method for Minimizing Nonconvex, Convex and Strongly Convex Functions

El houcine Bergou, INRA-KAUST, King Abdullah University of Science and Techn, Jeddah, Saudi Arabia

In this paper we consider the problem of unconstrained minimization of a smooth function in a setting where only function evaluations are possible. We design a novel randomized direct search (RDS) method and analyze its complexity. At each iteration, RDS generates a random search direction according to a certain fixed probability law. We analyze RDS method under several stepsize selection schemes (fixed, decreasing, estimated through nite differences, etc).

While deterministic direct search depends quadratically on  $n$  ( $n$  is the dimension of the space), our method depends linearly on  $n$ . We also propose a parallel version for RDS, with better iteration complexity bounds.

#### 2 - A Nonconvex Projection Method for Robust PCA

Aritra Dutta, King Abdullah University of Science and Technology, Division of Computer, Electrical and Mathemat, Al Khwarizmi Bldg 1, Thuwal, 23955-6900, Saudi Arabia, Filip Hanzely, Peter Richtarik

Robust principal component analysis (RPCA) is a well-studied problem with the goal of decomposing a matrix into the sum of low-rank and sparse components. In this paper, we propose a nonconvex feasibility reformulation of RPCA problem and apply an alternating projection method to solve it. To the best of our knowledge, we are the first to propose a method that solves RPCA problem without considering any objective function, convex relaxation, or surrogate convex constraints. We demonstrate through extensive numerical experiments on a variety of applications, including shadow removal, background estimation, face detection, and galaxy evolution, that our approach matches and often significantly outperforms current state-of-the-art in various ways.

#### 3 - An Inexact Regularized Stochastic Newton Method for Nonconvex Optimization

Xi He, Lehigh University, 837 Cedar Hill Drive, Allentown, PA, 18109, United States

We consider the minimization of nonconvex functions that typically arise in machine learning. In this paper, an inexact regularized stochastic Newton method (irSNT) within trust region scheme is purposed and it only requires Hessian-vector product oracle within the subproblem solver. irSNT achieves the best worst-case complexity regarding first-order stationary point convergence in terms of expectation and also has a second-order stationary point convergence guarantee with high probability. The Numerical experiments show that our proposed method can successfully solve optimization problems involving nonconvex objectives.

#### 4 - Improved Shrinkage Prediction under a Spiked Covariance Structure

Trambak Banerjee, University of Southern California, Los Angeles, CA, United States

We develop a novel shrinkage rule for prediction in a high dimensional non-exchangeable hierarchical Gaussian model with an unknown spiked covariance structure. We propose a family of commutative priors which, governed by a power hyper-parameter, ranges from perfect independence to highly dependent scenarios. It induces a wide class of predictors whose evaluation involves

quadratic forms of smooth functions of the unknown covariance. We propose an efficient adaptive prediction procedure which outperforms factor model based plug-in predictors by using uniformly consistent estimators of the quadratic forms involved in the coordinate-wise shrinkage strategies. We further improve our predictor by introducing possible reduction in its variability through a novel coordinate-wise shrinkage policy that only uses covariance level information and can be adaptively tuned using the sample eigen structure of the high dimensional spiked covariance model. Simulation studies are conducted to show that in many settings the proposed method substantially improves the performance of traditional plug-in based shrinkage procedures which first estimate the covariance and thereafter optimize over the hyper-parameters.

## ■ WC09

North Bldg 124B

### Healthcare Supply Chain

Sponsored: Manufacturing & Service Oper Mgmt

Sponsored Session

Chair: Liu Yang, Purdue University, New Albany, IN, 47150, United States

#### 1 - Service Level Satisfaction during Shortages for Health Networks

Erhun Kundakcioglu, Ozyegin University, Faculty of Engineering, Nisantep mah. Orman sok., Istanbul, 34794, Turkey, Cem Bozkir

In this study, we consider a system of healthcare providers, which face the same uncertain supply disruptions (e.g., nationwide, or worldwide drug shortages). Each hospital observes a stochastic demand and if demanded drug is unavailable, patients leave and receive care in another hospital system. As these unavailabilities hurt the brand value of the hospital system, we propose an inventory sharing mechanism for hospitals to mitigate the effect of uncertain supply disruptions. We explore reactive versus proactive inventory sharing approaches by investigating the effect of inventory related parameters on the service level of the system.

#### 2 - Improving Supply Chain Process Efficiency and Data Transparency Using Blockchain Technology

Raja Jayaraman, Khalifa University, P.O. Box 127788, Abu Dhabi, United Arab Emirates, Mecit Can Emre Simsekler

Supply chain logistics constitutes second largest expense for healthcare providers. The exponential growth, global sourcing of products, and increasing healthcare costs presents a compelling need to adopt innovative technology and real-time information sharing across the supply chain. The current system-wide inefficiencies in healthcare supply chains present an important and timely opportunity to improve the way transactions are recorded, stored and shared amongst stakeholders. In this talk I will present some of the significant challenges in supply chain data management, present several applications of blockchain technology along the product supply chain with potential pitfalls.

#### 3 - Optimizing Medical Supply Spend for GPOs and Healthcare Organizations

Liu Yang, Purdue University, Purdue Research Park, 3000 Technology Avenue, New Albany, IN, 47150, United States

Tier pricing is commonly used by medical suppliers to support corporate sales and market share strategies. Hospitals and GPOs have the opportunity to achieve significant savings in medical supply costs if they can effectively utilize tier pricing, but a major challenge is that tier structures vary by vendors and product categories, and may be based on volume, spend, and/or market share, and could be at a single facility or across facilities. This research presents a modeling framework that addresses the complexity of tiers with the consideration of one-way cross-reference and preference of individual facility. The application enables hospitals to achieve over 15% reduction in supply costs.

#### 4 - A Comparative Analysis of Healthcare and Traditional Supply Chains Using Financial Ratios

Balaraman Rajan, California State University East Bay, 25800 Carlos Bee Blvd, Hayward, CA, 94542, United States, Vishwanath Hegde

We compare and contrast the structure of healthcare and traditional supply chains using publicly available financial data. First, we develop a framework to analyze the healthcare supply chain and use the framework to compare with traditional supply chain. Then, by analyzing financial ratios, we find that companies that operate in different stages of the healthcare supply chain do exhibit different characteristics and differ from the companies that operate in comparable stages of traditional supply chains. We then draw inferences about the structural differences between healthcare supply chain and traditional supply chains based on the observed patterns.



## 5 - Individualized No-show Predictions: Effect on Clinic Overbooking and Appointment Reminders

Yutian Li, University of Science and Technology of China, Sammi Tang, Joseph Johnson, David Lubarsky

In this paper, we develop a Bayesian nested logit model which improves no-show prediction accuracy over the widely-used standard logit model. The accuracy gain arises from the individual patient-level coefficients provided by the Bayesian approach. Comparison of model fit on 12-months of appointment data shows the Bayesian model outperforms the standard logit model. In simulation studies, our results show that applying Bayesian model's prediction to scheduling algorithm can increase clinic's profit, reduce waiting cost when no-show probability is low and reduce overtime cost when no-show probability is high.

## WC11

North Bldg 125B

### Service Operations Management in the IT Industry

Sponsored: Manufacturing & Service Oper Mgmt

Sponsored Session

Chair: Aly Megahed, IBM, San Jose, CA, United States

#### 1 - Blockchain Technology in Supply Chains: Recent Developments and Future Research

Kaan Unnu, Rensselaer Polytechnic Institute, Center for Industrial Innovation, 110 8th Street, Troy, NY, 12180-3590, United States, Jennifer A. Pazour, Aly Megahed, Pralhad Deshpande, Chandra Narayanaswami

Blockchain technology has the potential to increase supply chain transparency and traceability by creating a robust and trusted decentralized source of information between different supply chain entities. We create a framework to categorize blockchain supply chain use cases based on a supply chain's echelons and scale, as well as information requirements. The presented framework systematically links potential blockchain benefits and use cases to existing supply chain literature and identifies new directions for future ORMS research topics.

#### 2 - Optimal Bidding for Highly-Valued IT Service Contracts: Theoretical Results and Practical Implications

Xiangyu Zhang, Cornell University, Ithaca, NY, United States, Aly Megahed, Peter Frazier

Information technology service providers compete to win highly-valued IT service contracts in a tender process. Prior literature shows that features other than price, including the service provider's relationship with the client, contribute to the client's selection because good relationship increases the provider's chance of winning the deal. Thus, it might be beneficial for the provider to lower their price for improving the client relationship and increasing their potential future contracts profits. In this work, we provide theoretical and numerical results illustrating the optimal price is lower than the myopic price which tries to maximize the expected profit of the current deal.

#### 3 - An Approach to "Predict+optimize" Rather than "Predict Then Optimize" with a Case Study in a Cloud Computing Application

Aly Megahed, IBM Research-Almaden, San Jose, CA, 95123, United States, Yingdong Lu, Mark S. Squillante

In a lot of applications, some uncertain parameters are predicted then fed into an optimization model to optimize for some task. For example, customer demand in a supply chain is predicted and then fed into an optimization model to find the optimal inventory levels. The traditional approach is to do the two tasks separately. We present a novel approach of doing them simultaneously (predict+optimize rather than predict then optimize) and apply it to a real-world service operations management application in cloud computing.

#### 4 - Black Box Combinatorial Optimization with Monotone Structure: Applications in the IT Services Industry

Nam Ho-Nguyen, Carnegie Mellon University, Tepper School of Business, 5000 Forbes Avenue, Pittsburgh, PA, 15213, United States, Giacomo Nannicini, Aly Megahed, Ahmed Nazeem

We consider the NP-hard problem of optimizing a black box function over binary vectors subject to linear constraints, where the black box function satisfies a monotonicity property. We discuss two potential applications for such a problem: automated solution design of IT services contracts, and product selection for retail bundles with uncertain cost. We develop an iterative framework for choosing new binary vectors to query via monotonic polynomial regression, and give a valid optimality criterion for stopping. To scale our approach, we discuss potential heuristics for different steps of our framework.

## WC12

North Bldg 126A

### Marketing II

Contributed Session

Chair: Mehmet Onal, Isik University, Ozyegin University, Istanbul, 34794, Turkey

#### 1 - An Analytical Model of Tier-based Loyalty Programs

Amir Gandomi, Assistant Professor, Hofstra University, 031 Weller Hall, Hempstead, NY, 11549-1340, United States, Mehdi Nourinejad

Loyalty programs are now a prominent market marketing strategy in many industries. They offer users a reward for becoming repeat consumers of a product. A prominent reward structure is the tier-based program that categorizes users according to their consumption intensity. Service providers like to design the tiers to maximize their expected profit. While research in this area is abundant, only a few provide analytical intuition of how the tiers should be set up. This study finds the optimal tier design of loyalty programs.

#### 2 - Benefit Formation and Enhancement

Hyowon Kim, Doctoral Student, Ohio State University, 540A Fisher Hall 2100 Neil Ave, Columbus, OH, 43210, United States, Dong Soo Kim, Greg M. Allenby

The distinction between attributes and benefits is at the heart of product development. Some attributes are benefit enabling in the sense that their presence signals that an offering is responsive to a benefit being sought, while their absence indicates that the product does not provide the benefit. Not all brands, for example, are seen as luxurious and specific brand names may be needed for consumers to consider an offering as providing luxury. Benefit formation hinges on these types of attributes being present, while other attributes only enhance a benefit that has already been formed. We develop a model to identify attributes that are critical to a benefit formation and apply it to conjoint datasets.

#### 3 - The Influence of Consumers' Regulatory Focus and Cultural Dimensions on Intentions to Purchase from Online Stores

Qiuling Li, University of Macau, Room 1048 E22, FBA, University of Macau, Macau, Macao, Chanthika Pornpitakpan

Consumer behavior in a multichannel context has increasingly received attention from academics. More and more people nowadays pursue online shopping. However, little research has examined how consumers' motivations and cultural dimensions affect their shopping channel preferences. Addressing this gap of knowledge, this research examines how consumers' regulatory focus (promotion focus vs. prevention focus) and cultural dimensions (i.e., individualism-collectivism, power distance, uncertainty avoidance, and masculinity-femininity, as identified by Hofstede) influence intentions to purchase from online stores versus physical stores. Several hypotheses are proposed.

#### 4 - A Price Markdown Analysis for Two Vertically Differentiated Items

Mehmet Onal, Ozyegin University, Istanbul, Turkey, Erhun Kundakcioglu

We consider a retail store that sells two vertically differentiated products that can substitute each other. We assume that the two products differ in quality and price, and target two different customer segments. We also assume that items lose their utility linearly with time and may require price adjustments so that cannibalization does not occur, i.e., consumers from one segment never buy items targeted for the other segment. We identify optimal solution properties and propose an efficient solution approach.

## WC13

North Bldg 126B

### Practice- Supply Chain Optimization II

Contributed Session

Chair: Jing Luo, University of Pittsburgh, Pittsburgh, PA, 15260, United States

#### 1 - Supply Chain Design with Multi-modal Shipping and Varying Lead Times

Gang Wang, University of Massachusetts Dartmouth, New Bedford, MA, 02740, United States

This paper considers a multi-echelon supply chain design considering production scheduling, varying lead times, and multiple shipping options. The problem is to determine three types of decisions: a) strategic decision-the location of processing centers; b) tactical decision-the shipping quantities from suppliers to processing centers; and c) operational decisions-order assignment of demand points to processing centers as well as production schedules at both the suppliers and processing centers. We study three scenarios: 1) commit to delivery; 2) nonlinear shipping costs; and 3) complete delivery.

## 2 - Manufacturing Network Design in the Pharmaceutical Industry under Life-cycle Demand

Gregor Blosssey, German Graduate School of Management and Law, Heilbronn, 74076, Germany, Gerd J. Hahn, Achim Koberstein

This research investigates the value of flexibility in manufacturing networks of the pharmaceutical industry. Pharmaceutical companies typically operate under life-cycle demand and are subject to two sources of uncertainty: demand uncertainty and product approval uncertainty. We present a two-stage stochastic programming model to determine the optimal level of capacity flexibility using multiple product allocations and outsourcing to contract manufacturing organizations. A numerical study is conducted with real-life data provided by a global pharmaceutical company.

## 3 - Integrated Order Acceptance, Production Planning, and Distribution Problems

Utku Koc, MEF University, Huzur Mah. Ayazaga Cad No: 4, Maslak-Sariyer-Istanbul, Istanbul, 34396, Turkey

We study a manufacturer's multi-period production planning problem to produce and ship a subset of available orders from a given set, meeting due window constraints, with the maximum profit. Each potential order has a revenue, size, and a due window. The profit is calculated as the revenue minus the transportation and inventory holding costs. The manufacturer can use different type of vehicles varying in their price and availability for outbound transportation. We study three different delivery characteristics: 1) whether orders can be split or not, 2) whether they can be consolidated or not, and 3) whether their sizes are restricted to be in integer multiples of vehicle capacities or not.

## 4 - The Optimal Width Decision for Cardboard Used in On Demand Packaging

Yihuan Yang, Hong Kong University of Science and Technology, Clear Water Bay, Kowloon, Hong Kong, Xiangtong Qi

For packaging problem, if the box could fit the products perfectly, there would be no packing fillers waste and less corrugated cardboard is used. The box-making machine with one long continuous piece of cardboard is used to cut the right-sized box. So the main problem is how to decide the proper width of the cardboard. The framework introduced in this paper can help to make better decisions so that the material waste is minimized. Compared with other naive methods, the policy obtained by our framework has better performance, especially when the penalty of exceeding capacity is high.

## 5 - Learning About a New Market from Supplier Perspective

Jing Luo, University of Pittsburgh, Pittsburgh, PA, 15208, United States

How to learn about a new market? What information and method are important for suppliers?

## WC15

North Bldg 127A

## Improving Services: Role of Incentives and Simple Policies

Sponsored: Manufacturing & Service Oper Mgmt/Service Operations

Sponsored Session

Chair: Ramandeep Randhawa, University of Southern California, Los Angeles, CA, 90089, United States

Chair: Achal Bassamboo

## 1 - Tipping for Fast Service: The Role of a Social Norm

Ran Snitkovsky, Tel Aviv University, Tel Aviv, Israel, Laurens G. Debo

We discuss how tipping for fast services emerges as a norm in a congested environment when after the joining and consumption phase, customers meet in a social market place where they compare each others' tips and incur disutility when these tips differ from each other.

## 2 - Managing Supply in the On-demand Economy: Flexible Workers or Full-time Employees

Jing Dong, Columbia University, Uris Hall 413, 3022 Broadway, New York, NY, 10027, United States, Rouba Ibrahim

We study the optimal staffing problem with a blended workforce. The goal is to strike a balance between staffing cost and service quality in presence of time-varying demand, supply side flexibility, and supply side uncertainty. We consider a queueing framework, where the number of servers is random due to the supply side uncertainty, and develop appropriate approximations that provide key insights into the staffing problem. We also study the impact of supply side uncertainty on the quality of service.

## 3 - Revenue Loss of Simple Contracts with Price and Delay Differentiated Customers

Abhishek Ghosh, Northwestern University, Evanston, IL, United States, Achal Bassamboo, Ramandeep Randhawa

We analyze a service firm that caters to price and delay sensitive customers by offering a menu of price-delay pairs. We study the gap in revenue for the firm under the worst-case valuation and delay sensitivity parameters. We also characterize the asymptotically optimal contract when the number of customer classes is large and provide the optimality conditions and the associated revenue loss.

## 4 - Dynamic Matching in School Choice: Efficient Seat Reassignment after Late Cancellations

Irene Yuan Lo, Columbia University, New York, NY, United States

When assigning scarce public school seats to students, a key operational issue is how to reassign seats that are vacated after an initial round of assignment. We propose a class of reassignment mechanisms, the Permuted Lottery Deferred Acceptance (PLDA) mechanisms, which generalize the commonly used Deferred Acceptance school choice mechanism and retain its desirable incentive and efficiency properties. We find that under natural conditions on demand all PLDA mechanisms achieve equivalent allocative welfare and the PLDA based on reversing the lottery order minimizes reassignment. Empirical investigations on data from NYC high school admissions support our theoretical findings.

## WC17

North Bldg 127C

## Tactical Assortment & Inventory Planning

Sponsored: Manufacturing & Service Oper Mgmt/Supply Chain

Sponsored Session

Chair: Shahab Derhami, ISyE Ga Tech, Atlanta, GA, 30332, United States

Co-Chair: Iman Dayarian, Georgia Institute of Technology, Atlanta, GA, 30332, United States

## 1 - Assortment Planning for Retailers of Substitutable High-value Products under Stochastic Demand

Shahab Derhami, Georgia Tech, NW, Atlanta, GA, 30332, United States, Iman Dayarian, Benoit Montreuil

We present challenges that retailers of high-value products face in determining the optimal assortment plan and inventory level decisions under stochastic demand, customer substitution, and long order lead-time constraints. We develop a scenario-based stochastic optimization model to address this problem and demonstrate the simulation results of implementing this model on the network of dealerships of a leading manufacturer of recreational vehicles in North America.

## 2 - Assortment Planning Under Product Substitution, Stochastic Demand, and Dealer Network Exchange

Iman Dayarian, Culverhouse College of Commerce, University of Alabama, Box 870226, Tuscaloosa, AL, 35487, United States, Shahab Derhami, Benoit Montreuil

We consider the context of assortment and inventory level planning of a network of dealers, offering high-value products. If a dealer is not able to meet a customer's demand based on his current inventory, he may offer an exchange to one of the neighboring dealers who possesses a product that satisfies the customer's demand. In such an environment, assortment recommendations to the dealers must take into account scenarios in which dealers attempt to collectively reduce the chance of lost sales in a district. We first formally describe this context, and then propose a centralized decision making procedure, which makes assortment and inventory level recommendations to the dealers within a district.

## 3 - Retail Availability Optimization in High-value Product Retail Networks

Jinyong Yim, Georgia Institute of Technology, Atlanta, GA, United States, Iman Dayarian, Shahab Derhami, Benoit Montreuil

We present a model to maximize product availability under stochastic demand and fast replenishment assumption in a network of hyperconnected dealerships of vehicles. Our model considers possible on-demand inventory transshipment between retail centers to satisfy the demand for an out-of-stock product. We present the results of implementing our model on the distribution network of a manufacturer of recreational vehicles in North America.

## ■ WC18

North Bldg 128A

**Facilities Planning, Design, and Location**

Contributed Session

Chair: Dnyaneshwar Mogale, Indian Institute of Technology, Kharagpur, Department of Industrial and Systems Engineer, Kharagpur, 721302, India

**1 - Vertical Expansion a Solution for Future Container Terminals**

Nima Zaerpour, Assistant Professor, California State University-San Marcos, San Marcos, CA, 92096-0001, United States

Container terminals play a major role in the growth of international trade. They need to accommodate the increasing number of containers while their space is limited, particularly close to major cities. One approach, often used in practice, is horizontal expansion through expensive land reclamation projects. In contrast, vertical expansion uses the available land more efficiently by storing containers in high-bay warehouses. In this paper, we study a next generation container terminal consisting of container storage towers. The results show that, compared to a traditional container block, the container tower can increase the annual throughput, while saving on the required footprint.

**2 - A Lagrangean Decomposition Approach for Dynamic Block Stacking Planning Under Deterministic Demand**

Hueon Lee, PhD Candidate, University of Arkansas, 4207 Bell Engineering Center, 1 University of Arkansas, Fayetteville, AR, 72701, United States, Kelly Sullivan, John A. White

In this research, the dynamic block stacking problem of determining which product lots to store in which storage row depths at each time epoch is considered for a block stacking storage system. The problem is formulated as an unsplitable multi-commodity flow problem based on a given layout of the system and known inventory cycles of product lots. To efficiently derive a good feasible solution to a large-scale instance, we propose a heuristics based on Lagrangean decomposition. It provides optimistic bounds of the optimal objective function value of the problem and generates feasible solutions using Lagrangean multipliers in an iterative process solving a Lagrangean dual formulation.

**3 - A Neighborhood Search Heuristic for the P-Median Problem with Continuous Demand**

Shane Auerbach, University of Wisconsin-Madison, Madison, WI, United States, Rebekah Dix

We develop a neighborhood search heuristic for the p-median problem with continuous demand. We discuss challenges to implementing the heuristic, propose solutions, and describe how it can be embedded in hybrid heuristics. We then apply the heuristic to computing optimal spatial allocations of facilities in US cities. In comparing these optimal allocations to the actual ones, we find that allocations of supermarkets do relatively poorly in minimizing transportation costs for consumers.

**4 - Robust Emergency Relief Supply Planning Incorporating Evacuation Side Uncertainty**

Jyotirmoy Dalal, Assistant Professor, Indian Institute of Management Lucknow, Prabandh Nagar, IIM Road, Uttar Pradesh, Lucknow, 226013, India, Halit Uster

We present an emergency response planning problem for foreseen disasters to supply relief by explicitly considering uncertainties in disaster location, intensity, duration, and evacuee-compliance. We present a robust optimization model that provides a decision maker with a choice of considering time-dependent or independent evacuation-related uncertainties. We devise a decomposition-based solution method for large-scale instances and conduct a case study to demonstrate the applicability of our approach.

**5 - An Integrated Sustainable Food Supply Chain Network Design Model for Optimization of Strategic & Tactical Decisions**

Dnyaneshwar G. Mogale, Research Scholar, Indian Institute of Technology, Kharagpur, West Bengal, Kharagpur, 721302, India, Sri Krishna Kumar, Manoj Kumar Tiwari

The developing countries are moving towards the modernized food supply chain system due to the growing population and post-harvest losses of food. In this study, a novel integrated multi-echelon, multi-period and inter-modal mathematical model is formulated to design the sustainable food grain supply chain network. The objective function of the model is to minimize the fixed cost of silo establishment, transportation, inventory and operational costs along with the cost of carbon dioxide emissions. The mathematical model is solved by using the CPLEX solver.

## ■ WC19

North Bldg 128B

**Joint Session RMP/Practice Curated: Modern Applications of Revenue Management**

Sponsored: Revenue Management &amp; Pricing

Sponsored Session

Chair: Maxime Cohen, NYU Stern, New York, NY, 10012, United States

Co-Chair: Renyu Zhang, New York University Shanghai, Shanghai, 200122, China

**1 - The Value of Personalized Pricing**

Michael Hamilton, Columbia University, New York, NY, United States, Adam Elmachtoub, Vishal Gupta

Increased access to high-quality customer information has fueled interest in personalized pricing strategies, i.e., strategies that predict an individual customer's valuation for a product and then offer them a customized price. While the appeal of personalized pricing is clear, it may also incur costs in the form of market research, investment in information technology, and branding risks. In light of these tradeoffs, in this work, we study the value of personalized pricing over simpler pricing strategies, and provide various closed-form upper bounds on the ratio that depend on simple statistics of the valuation distribution.

**2 - Power of Monotonic Reoptimized Pricing in Revenue Management with Strategic Customers**

Yiwei Chen, University of Cincinnati, Cincinnati, OH, United States, Stefanus Jasin

We study a canonical revenue management problem that a seller sells a single product with finite inventory over a finite horizon. Customers are forward looking who strategize their purchasing times. We propose a simple heuristic policy that requires the seller to repeatedly solve a simple static optimization problem by using the updated sales information. The price process is restricted to be non-decreasing over time. Thus, it incentivizes customers to behave myopically. We show that when the seller's initial inventory and the length of the horizon proportionally grow large (scaled by  $k$ ), the regret of our proposed policy is upper bounded by  $O(\log k)$ .

**3 - Competition and Cooperation for Two-sided Platforms**

Renyu Zhang, New York University Shanghai, 1555 Century Avenue, Shanghai, 200122, China, Maxime Cohen

We study the two-sided competition between online service platforms. We develop a new approach to characterize the existence and uniqueness of equilibrium when platforms compete for both demand and supply. Armed with this result, we then investigate cooperation between different ride-sharing platforms by introducing new joint services. The cooperation between different platforms is through profit sharing contracts. Interestingly, we show that a well-designed profit-sharing contract can will benefit both platforms. In addition, we find that one can design a profit-sharing contract that also benefits riders and drivers.

**4 - Electricity Pricing with Limited Consumer Response**

Saed Alizamir, Yale University, 206 Elm Street, P.O. Box 209052, New Haven, CT, 06520, United States, Shouqiang Wang, Fariba Farajbakhsh

Retail electricity markets are characterized by nuanced features that distinguish them from mainstream retail settings. Specifically, the consumption quantity is influenced by factors not controlled by the consumer (e.g., weather), and consumption decisions can be readjusted on a continuous basis. In this paper, we study a monopolistic utility firm's pricing decision in a retail electricity market. Using a rational inattention framework, we construct a demand model for consumers, whose consumption decisions demonstrate limited response to their ambient environment for a given price. Implications on social welfare and system reliability are drawn.



## ■ WC20

North Bldg 129A

### Matching Markets

Sponsored: Revenue Management & Pricing

Sponsored Session

Chair: Ozge Sahin, Johns Hopkins University, Brooklyn, NY, 11222, United States

#### 1 - Information Acquisition Costs of Matching Markets

Irene Yuan Lo, Columbia University, New York, NY, 10025-6186, United States

Centralized matching mechanisms are typically designed assuming all participants know their preferences. We study the welfare effects of costly information acquisition in a matching model where school priorities are known, but students learn their preferences at a cost. Traditional matching mechanisms that do not account for costly information acquisition can lead to information deadlocks, where it is strictly optimal for every agent to wait for others to provide information before learning their own preferences. We characterize the optimal omniscient mechanism using an admission cutoff structure and propose mechanisms that learn market information to approximate the optimal outcome.

#### 2 - Bonus Competition in the Gig Economy

Xiaoyan Liu, Cornell University, Sage Hall, Ithaca, NY, 14853, United States, Yao Cui, Li Chen

Unlike traditional firms, service platforms in the gig economy need to compete for both customers and independent service providers. We study how service platforms can offer bonuses to attract service providers in a competitive setting, and investigate the implications of platforms' bonus strategies on the stockholders of the gig economy.

#### 3 - Nonlinear Pricing for Online Matching Markets

Ozge Sahin, Johns Hopkins University, Baltimore, MD, 21231, United States

Online matching platforms such as eHarmony lack a straightforward quality measure, and users' preferences are often fluid and subjective. A large and active user base is a platform's most precious asset. We investigate how pricing mechanisms can help manage user entry, and exit behavior to the matching platform to improve social welfare and firm revenues.

## ■ WC21

North Bldg 129B

### Innovative Practices in Pricing and Revenue Management

Sponsored: Revenue Management & Pricing

Sponsored Session

Chair: Pelin Pekgun, University of South Carolina, Columbia, SC, 29205, United States

Co-Chair: Ovunc Yilmaz, University of Notre Dame, South Bend, IN, 46617, United States

#### 1 - Inventory Count-down Information

Laura Wagner, NIF 501082522, Lisbon, 1200/830, Portugal, Edu Calvo, Ruomeng Cui

Online retailers provide the scarcity message such as count-down inventory information to alert consumers that there are only a few units left. Collaborating with the leading flash-deal retailer in Spain, which displays the limited-inventory information for the last five inventory units, we explore how it affects consumer purchasing behavior. We use a difference-in-difference approach to examine the impact on sales, returns and net sales. We find that the scarcity message causally attracts more sales, the return rate remains the same and net sales increase. We also investigate the moderating effect of product characteristics, and how the scarcity effect varies across web and mobile channels.

#### 2 - The Effect of Platform Selection and Underreporting Biases on Tripadvisor Ratings

Saram Han, 110 Joanne Dr., Ithaca, NY, 14850, United States  
Cornell SC Johnson College of Business, Ithaca, NY, United States

This study shows how an underreporting bias affects the shape and average of an online satisfaction rating in TripAdvisor in conjunction with a platform selection bias. We show that since expert reviewers' expectations for service quality is hard to meet, most of the properties experience negative platform selection bias. The direction of the underreporting bias is determined by the reporting propensity that depends on how strongly the reviewers are motivated to report their satisfaction, whether to complement or complain. The bounds of the reporting propensity are determined by the reviewers' expertise with the platform.

#### 3 - The Sharing Economy and Housing Affordability: Evidence from Airbnb

Davide Proserpio, University of Southern California, 701 Exposition Blvd, HOH 332, Los Angeles, CA, 90034, United States

We assess the impact of home-sharing on residential house prices and rents. Using a dataset of Airbnb listings from the entire United States and an instrumental variables estimation strategy, we find that a 1% increase in Airbnb listings leads to a 0.018% increase in rents and a 0.026% increase in house prices at the median owner-occupancy rate zip code. The effect is moderated by the share of owner-occupiers, a result consistent with absentee landlords reallocating their homes from the long-term rental market to the short-term rental market. A simple model rationalizes these findings.

#### 4 - The Effect of User Generated Content on Hotel Demand under a Competitive Framework

Sanghoon Cho, University of South Carolina, 1014 Greene Street, Columbia, SC, United States, Pelin Pekgun, Ram Janakiraman

We investigate the impact of user generated content on hotel performance as captured by actual hotel bookings. We propose and estimate a consumer learning model that focuses on the effect of review sentiment on hotel demand taking into account the effect of competition and hotel prices. Drawing on prospect theory, we cast the competitive perception spillover effects in the form of gains and losses in review sentiment, and find that the relative negative sentiment has more influence on bookings than the relative positive sentiment.

## ■ WC22

North Bldg 130

### Practice – Finance Theory & Financial Engineering I

Contributed Session

Chair: Min Dai, National University of Singapore, Dept of Math, Singapore, 119076

#### 1 - Investment and Financing for Cash Flow Discounted With Group Diversity

Zhaojun Yang, Southern University of Science and Technology, 1088 Xueyuan Avenue, Fourth Building of the Faculty Apartment, Shenzhen, 518055, China

We consider a firm's investment and financing decisions made by a group of which each individual may utilize different discount rates to price cash flow generated by the investment project. We show that a higher degree of decreasing impatience or a greater group diversity increases the project value, accelerates investment and postpones default. Both the value of the investment option and the optimal leverage increase with the degree of the decreasing impatience and the group diversity. The inefficiency from asset substitution increases but it from debt overhang decreases with the degree of the decreasing impatience and the group diversity. Our predictions are documented by empirical evidences.

#### 2 - Making the Most Out of Market Forecasts Based on Linear Regression

Hamed Khaledi, PhD Student, Broad Graduate School of Management, 632 Bogue Street, North Business College Complex, Room N203, East Lansing, MI, 48825, United States

This paper presents a mathematical model to make optimal trading decisions using forecasts made by multivariate regression. Given that these results are uncertain, the model maximizes the expected profit from opening and closing trade positions. To this end, a dynamic programming approach is employed. We first find the optimal take profit levels associated with buy and sell positions. Then we decide to buy, sell or wait, based on the maximum expected profit in each case. The approach is applied to find the optimal strategy for trading GBPUSD rate based on a multivariate regression model fitted to the historical daily data in the FOREX Market.

#### 3 - The Design of a Global Supply Chain by Integrating Operational and Financial Strategies

Mengyue Wang, PHD, Tsinghua University, Beijing, China, Hongxuan Huang

In this paper, a scenario-based mixed-integer linear programming model is proposed for designing a flexible capital-constrained global supply chain (CCGSC) in which integrate the applying for loans with operational strategies such as constructing, or leasing facilities and equipments to meet uncertain demands and exchange rates. The research on the CCGSC also indicates that the complementary property holds for both the remaining capital of loans with higher costs and another available loan with a lower cost under certain conditions. A case study is also presented to illustrate effectiveness and efficiency of the scenario-based approach.

#### 4 - Adjusted Portfolio Selection Model Reflecting the End of the Year Effect of Global Economic Growth

Jihye Yang, PhD Student, Yonsei University, 50 Yonsei-ro, Seodaemun-gu, Seoul, 03722, Korea, Republic of, Hongseon Kim, Seongmoon Kim

This study suggests improved investment strategy based on adjusted portfolio selection model reflecting The End of the Year Effect, a strong negative relation between end of the year global economic growth and average stock returns (Stig V.2016). We can adjust the proportion of capital invested in risk assets and risk-free assets on the rebalancing date according to end of the year global economic growth. Specifically, if end of the year global economic growth is high, we decrease the proportion of capital invested in risk assets and increase risk-free assets in order to avoid risk. Thus, we can expect superior performance using the proposed investment strategy reflecting The End of the Year Effect.

#### 5 - Optimal Control of an Individual Savings Account in a Defined Contribution Pension System

Luis Chavez-Bedoya, Professor, Universidad Esan, Nestor Bermudez 191, Chorrillos, Lima, LIMA 9, Peru, Ranu Castaneda

In this article, we examine the optimal investment strategy of a particular utility-maximizer participant in a defined contribution pension fund under the system of individual accounts; but, we assume deterministic functions for the fees paid to the pension fund administrator and for the contribution rate of the participant. Finally, we perform a thorough comparison between the two different types of fees (on balance and on flow) and we apply our results to the Peruvian Private Pension System in order to determine equivalent fees on balance and flow.

#### 6 - A Dynamic Mean Variance Analysis with Application to Robo Advising

Min Dai, National University of Singapore, 10 Lower Kent Ridge Road, Dept of Math, Singapore, 119076, Singapore, Hanqing Jin, Steven Kou, Yuhong Xu

In asset allocation for robo-advising, it is desirable to elicit investors' risk profile via several simple online questions and to provide advice consistent with conventional investment wisdom (e.g. rich people should invest more money in risky assets, and for long-term investment people should not short sell major stock indices whose returns are higher than the risk-free rate). We propose a dynamic portfolio choice model with the mean-variance criterion for portfolio log-returns that meets the two challenges. The model yields analytical and time-consistent optimal portfolio policies.

## WC23

North Bldg 131A

### Optimal Stopping and Stochastic Control for Financial and Engineering Applications

Sponsored: Finance

Sponsored Session

Chair: Philip Ernst, Rice University, Houston, TX, 8, United States

#### 1 - When is it Best to Follow the Leader

Quan Zhou, Rice University, 6100 Main St. Duncan Hall 2076, Houston, TX, 77005, United States, Philip Ernst, L. C. G. Rogers

We study a classical continuous-time optimal scanning problem with  $N$  boxes. An object is hidden in one box according to a given prior distribution. The goal is to determine which box contains the object. When we search a box, we get a signal evolving as a Brownian motion with a constant drift if the box contains the object, or as a Brownian motion with drift zero otherwise. This problem was first studied by Posner and Rumsey (1966), who conjectured that the optimal policy is to always observe the box with the largest posterior. However, we prove that this is not true in general and give counterexamples for some specific prior distributions. It remains unclear whether this policy is optimal for the uniform prior.

#### 2 - The Value of Foresight

Philip Ernst, 6100 Main St, Houston, TX, 77005, United States, L.C.G. Rogers, Quan Zhou

Suppose you have one unit of stock, currently worth 1, which you must sell before time  $T$ . The Optional Sampling Theorem tells us that whatever stopping time we choose to sell, the expected discounted value we get when we sell will be 1. Suppose however that we are able to see  $\$a$  units of time into the future, and base our stopping rule on that; we should be able to do better than expected value 1. But how much better can we do? And how would we exploit the additional information? The optimal solution to this problem will never be found, but in this paper we establish remarkably close bounds on the value of the problem, and we derive a fairly simple exercise rule that manages to extract most of the value of foresight.

#### 3 - Optimal Allocation of Retirement Portfolios

Stan Uryasev, University of Florida-Gainesville, AOD, 303 Weilhall, Gainesville, FL, 32611, United States, Giorgi Pertalia, Morton Lane, Matthew Murphy

Without a pension the function of the savings is to provide post-employment income to a retiree. At the same time, most retirees will want to leave an estate to their heirs. Guaranteed income can be acquired by investing in an annuity. However, that decision necessarily takes funds away from investment alternatives that might grow the estate. The decision is made even more complicated because one does not know how long one will live. This paper presents a stochastic programming model of an optimal portfolio for the retiree.

#### 4 - Non-linear Risk Parity Portfolios

Nathan Lassance, Universit  Catholique de Louvain, Louvain-la-Neuve, Belgium, Victor DeMiguel, Fr d ric Vins

Factor risk parity portfolios are defined such that the portfolio risk is projected homogeneously on the basis of uncorrelated principal components. This basis is however arbitrary: it is one basis of uncorrelated factors out of infinitely many others, each yielding different optimal solutions. Instead, looking for a basis of independent factors is more meaningful for non-Gaussian assets, and removes this arbitrariness. This basis is found by independent component analysis (ICA), a non-linear higher-order extension of PCA. ICA also provides a simplified setting to deal with higher-order risk parity. The proposed portfolios exhibit solid performances in terms of Sharpe ratio and downside risk.

## WC24

North Bldg 131B

### Practice- Programming and Applications I

Contributed Session

Chair: Frank Muldoon, Applied Materials, Piedmont, SC, 29673, United States

#### 1 - Revised Adaptive Linear Programming Algorithm

Lin Guo, University of Oklahoma, Norman, OK, 73071, United States

We revise Adaptive Linear Programming (ALP) to have fewer heuristics in determining the value of critical parameters, using the insight that we get through post-solution analysis. ALP is a second-order derivative linearization algorithm. The algorithm has limitations: 1) the value of critical parameters are determined with heuristics; 2) we use the critical parameters to control the approximation accuracy as well as convergence efficiency, but little knowledge of their tradeoffs has been used to make rules of the parameters setting and updating. To fill in these gaps, we revise the ALP algorithm to self-update the critical parameters using the knowledge from the post-solution analysis.

#### 2 - Managing Navigation Channel Traffic and Anchorage Area Utilization of a Container Port

Shuai Jia, The Hong Kong Polytechnic University, Kowloon, Hong Kong, Chung-Lun Li, Zhou Xu

Navigation channels are fairways for vessels to travel in and out of a container terminal basin. The capacity and availability of a navigation channel is restricted by the traffic lanes and tides. When the navigation channels run out of capacity, the anchorage areas can serve as a buffer. This paper aims to simultaneously optimize the navigation channel traffic and anchorage area utilization of a container port. We provide a mixed integer program of the problem, analyze its complexity, and propose a Lagrangian relaxation heuristic for solving the problem. Computational performance of the heuristic is evaluated on problem instances generated based on the operational data of a port in Shanghai.

#### 3 - On Sensitivity Analysis of Linear Integer Program: The Case of Stochastic Programming and Non-linearity in Parameters

CY (Chor-yiu) Sin, National Tsing Hua University, Kuang-Fu Road, Hsinchu, 30013, Taiwan

A stochastic programming with  $P$  states can well be formulated as a deterministic programming with  $P-1$  probabilities. In this and the case with non-linearity in parameters, when one parameter changes the others may also change. Consequently the existing sensitivity analysis in the linear integer program may not be applicable, as it confines the attention to one-parameter change. This paper considers a special type of Lagrangian dual function which renders strong duality. Using this Lagrangian dual function, we first generalize the result in Shapiro (1977) to multi-parameter cases. Further, we show with synthetic data that our analyses save a lot of computer time in large-scale optimization.

**4 - Data-driven Quickest Detection of Customer Churn**

Roozbeh Yousefi, Queen's University, Kingston, ON, K7M9H1, Canada, Jue Wang

In many service industries, customers may stop returning for service without informing the service provider. It is important for the service provider to detect such soft churn as quickly as possible, so that appropriate retention can be made. We develop a churn detection model based on partially observable Markov decision processes in which both transition and observation probabilities are unknown. The optimal policy must balance churn detection with parameter learning. We characterize the structure of the optimal policy and show that the infinite-dimensional belief space can be collapsed to two-dimension, making the optimal policy computationally feasible.

**5 - Sales & Operations Planning Linear Programming Model Used by Semiconductor Manufactures**

Frank Muldoon, Operations Research Application Engineer, Applied Materials, 5225 W. Wiley Post Way, Suite 275, Salt Lake City, UT, 84116, United States

In today's competitive environment, semiconductor manufacturers face the unending challenge of planning for ever-changing customer demands. Factory managers must plan for new orders within existing demands in order to avoid capacity shortfalls of available resources. We propose a linear programming formulation that models this capacity planning challenge in Applied Material's Advanced Productivity Family software. The result of this optimization identifies demands that cannot be satisfied and resource capacity deficits week, months, or even years in advance giving planners time to adjust. We discuss the implementation of our system within a semi-conductor assembly and test facility.

**WC26**

North Bldg 132A

**System Design for Emergency Medical Services**

Sponsored: Service Science

Sponsored Session

Chair: Ozgur M. Araz, University of Nebraska, Lincoln, NE, 68588-0491, United States

**1 - Emergency Service Network Design with Constraint Relaxation**

Adrian Ramirez Nafarrate, Professor, Universidad Panamericana, Zapopan, Mexico, Ozgur M. Araz, John W. Fowler

Some emergency scenarios require deploying a limited amount of resources to deliver service within a target time. However, the available resources in large-scale scenarios may make the location-allocation problem infeasible. We propose a modeling approach that represents this situation and present a set of algorithms to relax capacity at each service site and/or time to complete the service operations. The results show how decision makers can incentivize using one type of resource and when is better to balance adding more capacity or service time. In addition, we analyze how the resource allocation strategy interacts with the number of open sites.

**2 - Bed Forecasting System in the Emergency Healthcare Network**

Shao-Jen Weng, Tunghai University, Taichung City, Taiwan

Because of high complexity in Emergency Departments, the ability to analyze the present and future status of resource availability is difficult. The goal of this research is to use simulation to create a cloud-based forecasting system called an available bed forecasting system (ABFS) in a regional hospital network in Taiwan in order to provide near-contemporaneous information to Emergency Department personnel and to EMTs in an effort to efficiently predict the optimal hospital to which patients should be transported based on bed and resource availability.

**3 - Forecasting Influenza for Emergency Planning**

Zeynep Ertem, University of Texas at Austin, Austin, TX, 78723, United States

Timely and accurate estimates of influenza prevalence, particularly of severe cases requiring hospitalization, can improve control measures to deal with medical emergencies. Our framework uses multi-linear regression to combine forecasts from multiple data sources and optimization with forward selection to choose the most predictive combinations of data sources. We show that the systematic integration of complementary data sources can improve forecast accuracy over single data sources. The optimal combination of predictors includes public health surveillance data and commercially available electronic medical records, but neither search engine nor social media data.

**WC27**

North Bldg 132B

**Information Systems I**

Contributed Session

Chair: Fengmei Gong, University of La Verne, La Verne, CA, 91750, United States

**1 - Do Organizational Controls Influence the Effectiveness of Waste Management Green IT Systems?**

Xue Ning, University of Colorado Denver, 1475 Lawrence Street, Denver, CO, 80202, United States, Dobin Yim, Jiban Khuntia

This study explores how organizational controls influence the effectiveness of life cycle assessment systems (LCAS) for waste management in hotels. Effectiveness is measured through total waste generated by hotels and waste management cost reduction. Analysis of secondary data for 1,277 hotels of a large multinational hotel chain is used to find evidence for hypotheses. Study informs to green information technology and business value streams of research.

**2 - Can Individuals Benefit from the Wisdom of Crowds?**

Joshua Becker, PhD Candidate, University of Pennsylvania, 3620 Walnut Street, Suite 200, Philadelphia, PA, 19104, United States, Damon Centola

Groups can form remarkably accurate beliefs even when group members are wildly inaccurate, an empirical phenomenon known as the "wisdom of crowds." This accuracy gain, however, offers no direct benefit to individual group members. Moreover, theoretical accounts argue that individuals must be independent to preserve group accuracy, preventing social learning. We test an alternative theory predicting that structured information exchange networks allow social learning while preserving group accuracy. Experimental subjects made financial forecasts before and after learning the beliefs of peers. Information exchange produced a 25% decrease in error without harming the wisdom of the crowd.

**3 - Timely Production of Crowdsourced Answers in Stack Overflow**

Orcun Temizkan, Ozyegin University, Cekmekoy Kampusu, AB2 324, Nisantepe Mah. Orman Sok. No: 34-36, Istanbul, 34794, Turkey, Ram Kumar

Question answering websites that involve volunteer participants such as Stack Overflow are becoming increasingly popular. They represent a crowdsourced knowledge creation process, and thus are large repositories of knowledge. In addition to the quality of answers, a process that results in high quality answers in a relatively short time frame is also important. Therefore, we focus on the generation of high quality answers in a timely manner. We present a survival analysis model of generating high quality answers. We also discuss research and managerial implications.

**4 - Are Online Ratings Relative in Competitive Markets?****A Mean-field Estimation Approach**

Mingwen Yang, University of Texas at Dallas, Richardson, TX, 75080, United States, Vijay S. Mookerjee, Eric Zheng, Hongyu Chen

We study user ratings in China's tourism market, where different tours compete with one another for business. The focus is on how user ratings affect the sales of competing tours and how the ratings of these tours are optimally managed over time. We estimate the joint evolution of tour ratings and sales assuming that tour managers act rationally to maximize profit over time. The data for the study comes from sales and review information collected over time for tours listed on Ctrip.com, the largest travel aggregator in China. Our estimation approach uses controlled diffusion processes to jointly estimate two stochastic processes for each tour: sales and review ratings.

**5 - The Limitation of Current Digital Gamification Systems and the Alternative Strategy for Sustainable User Engagement**

Jaewan Lim, PhD Student, University of Maryland, Baltimore County, 1000 Hilltop Cir, Baltimore, MD, 21250, United States

In a large number of studies, it has been demonstrated that digital gamification strategy improves the engagement of customer. However, some gamification systems expose short life cycle pattern, resulting in the decrease of the system effectiveness. There is a paucity of literature on this problem. In this regard, the focus of this research is to identify the limitation of current digital gamification systems and propose the model for increasing the retention rate and sustainable user engagement.

**6 - The Impact of Information Technology on Technical Efficiency Evidence from Industry**

Fengmei Gong, University of La Verne, 1950 Third Street, La Verne, CA, 91750, United States, Tong Zeng, Yingxia Cao

This study intends to examine the impact of Information Technology (IT) investment on technical efficiency across different industries in the U.S. economy. Previous related studies are mostly based on firm level and country-level evidence, this study adds to the literature by providing industry-level evidence.



## ■ WC28

North Bldg 221A

**Practice- Transportation-Operations II**

Contributed Session

Chair: Young-Ji Byon, Khalifa University of Science Technology, Al Saada Street and Airport Road, P.O. Box 127788, Abu Dhabi, 127788, United Arab Emirates

**1 - Layout Optimization of Business Outlets for Railway Scattered Goods Express**

Yongxiang Zhang, Southwest Jiaotong University, Chengdu, 610031, China, Qingwei Zhong, Qiyuan Peng, Wenxin Li

Due to the characteristics of scattered goods, how to optimize the layout of business outlets for railway scattered goods express in transportation network has become a worth researching problem. In this paper, firstly, portraying the railway scattered goods express network as a two-level single assignment network composed of three-layer logistics nodes. Then, based on the construction of the assignment network, a mixed integer programming model is established to minimize the total cost of the railway scattered goods express network. Finally, a real-world case of Chengdu is used to verify the effectiveness of the proposed method.

**2 - The Access Management Application for Improving Performance of a Signalized Intersection**

Maxim A. Dulebenets, Florida A&M University-Florida State University, Tallahassee, FL, 32311, United States, Amir Masoud Rahimi, Arash Mazaheri, Junayed Pasha, Masoud Kavoosi

Different access management techniques have been widely used to improve the traffic flow conditions in large metropolitan areas. This study aims to assess the effects of replacing the direct left turn with the right-turn U-turn maneuver at the signalized intersection performance. The SimTraffic and AIMSUM simulation models are developed to estimate the major intersection and network performance indicators. The computational experiments are conducted for one of the busiest intersections in Tehran metropolitan area (Iran) and demonstrate advantages from the proposed access management treatment.

**3 - Optimizing Intermodal Terminal Operations Base Model through Simulation Modeling: A Comparison on Different Settings**

Fatemeh Rezaeifar, PhD Candidate, University of Texas at Arlington, Arlington, TX, 76010, United States, Mohammad Najafi, Brian L. Huff

Increasing demand in terminals will raise the risk of terminal congestion due to the increase in system bottlenecks. This research develops a framework for optimizing the capacity of intermodal Underground Freight Transportation (UFT) terminals. To test the variations of performance indicators a discrete event simulation model is used for two scenarios (with and without a stack-yard). The findings confirm that the percentage of bottlenecks in both scenarios significantly decreased and Scenario No. 1 and No. 2 ship respectively 34% and 59% more than the annual expected shipped containers. Also, Scenario No. 2 can handle 25% more containers per year.

**4 - A Near Real-time Algorithm for System Optimal Dynamic Traffic Assignment with Multiple Origins and Destinations**

Mehrzad Mehrabipour, Washington State University, 1630 NE Valley Road, Apt B204, Pullman, WA, 99164, United States, Ali Hajbabaie

This study introduces an efficient algorithm to find near-optimal solutions to the System Optimal Dynamic Traffic Assignment Problem (SODTA) with multiple origins and destinations in real-time. The proposed Distributed Optimization and Coordination Algorithm decomposes the network-level traffic assignment problem into several intersection-level subproblems that can be solved individually. The complexity of the problem is significantly reduced, and the solutions can be found in real-time. The results in a case study of 20 intersections are compared with the global optimal solution and the maximum observed optimality gap was 5%.

**5 - Air Traffic Noise Monitoring with ADS-B Signal, GIS, and BIM in UAE**

Young-Ji Byon, Associate Professor, Khalifa University of Science and Technology, Abu Dhabi, 127788, United Arab Emirates, Tadahi Kishida

It is essential to monitor and assess air traffic noise levels in the vicinity of airports for impacts on residential and commercial zones in UAE. Recently, commercial airlines have started equipping their planes with ADS-B signal emitters. A GIS layer in a raster format can accumulate the noise in a quantifiable unit of decibels in associated cells for various tempo-spatial analyses of air traffic noises. In order to accurately account for the noise on the ground surface, digital elevation model integrated with building information modeling can provide noise projection on buildings.

## ■ WC29

North Bldg 221B

**System and Operation Issues in Wireless Charging Electric Vehicles and Electrified Road Infrastructure**

Sponsored: TSL/Urban Transportation

Sponsored Session

Chair: Young Jae Jang, KAIST, Daejeon, 34141, Korea, Republic of

**1 - Dynamic Charging Infrastructure Deployment for Plug-in Hybrid Electric Trucks**

Ziqi Song, Utah State University, 4110 Old Main Hill, Logan, UT, 84322-4110, United States, Zhaocai Liu

Inspired by the rapid development of charging-while-driving (CWD) technology, plans are ongoing in government agencies worldwide for the development of electrified road freight transportation systems through the deployment of dynamic charging lanes. This en route method for the charging of plug-in hybrid electric trucks is expected to supplement the more conventional charging technique, thus enabling significant reduction in fossil fuel consumption and pollutant emission from road freight transportation. In this study, we investigated the optimal deployment of dynamic charging lanes for plug-in hybrid electric trucks.

**2 - V2V Wireless Power Transfer between Electric Automated Vehicles**

Mojtaba Abdolmaleki, University of Michigan, Ann, MI, 48109, United States, Neda Masoud

To date, three major concerns have hindered widespread adoption of electric vehicles (EVs): the high cost of batteries, a lack of sufficient charging infrastructure, and the limited driving range of EVs. This proposal tackles all three challenges by introducing a new concept of vehicle-to-vehicle (V2V) tethered power transfer (TPT) between EVs to facilitate frequent, real-time, and on-demand charging. We quantify the impact of adopting this technology in terms of reductions in infrastructure investments that would otherwise be required, and energy savings.

**3 - The State of the Art in Operation and System Study on Wireless Charging Electric Vehicle Systems**

Young Jae Jang, KAIST, Department of Industrial and Systems Engineer, Yuseong-Gu, Daejeon, 34141, Korea, Republic of

The state-of-the-art in operations and systems-related studies of wireless charging electric vehicles (EVs) is presented. The wireless charging EV is one of emerging transportation systems in which the EV's battery is charged via wireless power transfer (WPT) technology. The system makes use of charging infrastructure embedded under the surface of the road that transfers electric power to the vehicle while it is in transit. The goal of the presentation is to provide researchers and practitioners with an overview of research trends and to provide a guide to promising future research directions.

**4 - The Impact of Charging Infrastructure on Electrified Shared Mobility Systems**

Zhengtian Xu, University of Michigan, Ann Arbor, MI, 48105-2540, United States, Zhibin Chen, Daniel Vignon, Yafeng Yin

In the foreseeable future, electric vehicles (EVs) will largely permeate the shared-mobility market. Considering EVs' scant battery size, the long charging time, and the scarce distribution of charging facilities at the early stage, a suitable deployment of charging infrastructure can significantly advantage the movements and reduce the charging delay of shared EVs, thereby benefiting the system operations. With such a quest, this study investigates the impacts of different types of charging infrastructure, including charging stations, swapping stations, and charging lanes, on the performance of shared mobility systems.

## ■ WC30

North Bldg 221C

**Warehousing**

Sponsored: TSL/Facility Logistics

Sponsored Session

Chair: Reem Khir, Georgia Institute of Technology, Atlanta, GA, United States

**1 - An Integrated Cluster-based Storage Assignment Policy**Yafeng YinB.M. De Koster, Erasmus University-Rotterdam,  
Planciusdreef 47, Bergschenhoek, 2661 RK, Netherlands,  
Masoud Mirzaei, Nima Zaerpour

As ecommerce is growing, companies need more efficient warehouses. Amazon for example, allocates multiple correlated products on the same pod to reduce retrieval time. Turnover-based storage policies, only consider the frequency at which each product has been requested and ignore the frequency at which products are ordered jointly. To consider both information, we propose an integrated cluster allocation storage assignment model which minimizes the total retrieval time. Compared to full turnover-based policy, the proposed model can save up to 22%, in total retrieval time in an automated storage and retrieval system. However, it is data intensive and benefits depend largely on the order pattern.

**2 - Dynamic Wireless Charging Lane Location Optimization in a Congested Warehouse**Liu Su, University of South Florida, ENG 302, Tampa, FL, 33620,  
United States, Sung Hoon Chung, Kibaek Kim, Changhyun Kwon

Forklifts with batteries are often used for material handling in a warehouse. With dynamic wireless charging, forklifts can be charged without work interruption. The optimal locations of dynamic wireless charging lanes are selected under the workflow congestion in a warehouse facility. Considering the uncertainty of demands, we formulate the wireless charging lane location problem as a two-stage stochastic programming model and propose a numerical method.

**3 - Optimization of Sorting Center Operations in Express Parcel Delivery Network**Reem Khir, Georgia Institute of Technology, Atlanta, GA,  
United States, Alan Erera, Alejandro Toriello

We model a two-stage sorting process as a mixed-integer program to enable making decisions related to parcels' routing and scheduling, and resource management and planning. The objective is to find a path for each parcel from the time it enters the sorting center to the time it leaves it such that each parcel finishes its sorting requirements no later than its cut-off time while the operational cost is minimized. Since finding optimal solutions of this problem is difficult for large-scale instances that are commonly found in practice, we investigate various ways to solve the problem using local search mechanisms.

## ■ WC32

North Bldg 222B

**Reverse Logistics & Supply Chains**

Contributed Session

Chair: Xianghui (Richard) Peng, Eastern Washington University, 668 N. Riverpoint Blvd., Room 360, Spokane, WA, 99202-1677, United States

**1 - Cross-training Policies in Repairable Spare Part Supply Systems**Andrei Sleptchenko, Assistant Professor, Khalifa University, P.O.  
Box 127788, Abu Dhabi, United Arab Emirates, Hasan Turan

In this talk, several results on the usage of Cross-Training Policies in Supply Systems for Repairable Spare Parts will be summarized. The presented results comprise simulation-based evolutionary heuristics for total cost optimization, as well as simple and scalable heuristics based on pooling of different parts into clusters by exploiting similarities of the repairable parts. The obtained results demonstrate that the optimal cross-training policies, or skill-server assignments, can help to improve the utilization of the repair servers and reduce the total system cost.

**2 - Determining the Optimal Collection Policy for Returned Products in the Reverse Supply Chain**Moulik Kapadia, Northeastern University, Boston, MA,  
United States, Nizar Zaarour, Emanuel Melachrinoudis

A growing number of firms are facing the challenge of driving down costs in their reverse logistics network while maintaining a strategic competitive advantage through great customer service. This work focuses on the comparison of different collection policies that reduce the impact of product returns on a firm's operational costs by leveraging economies of scale and optimizing the collection period across multiple initial collection points (ICPs) in a network before transshipping the returned products to a centralized return center (CRC).

**3 - Coordination, Information Sharing, and Return Variabilities in Closed-loop Supply Chains**Juan Pedro Sepulveda-Rojas, Associate Professor, University of  
Santiago of Chile, Avda Ecuador 3769, Santiago de Chile, Chile

We analyze quantitatively coordination, information sharing and return variabilities in a closed-loop supply chain context. We evaluate the value of coordination for operational decisions (in the context of inventory management decisions). One of the more important characteristics of the closed-loop supply chain context is the addition of uncertainties about returns.

Thus, this work is focused on coordination problems imposed by the flows of returned products. In particular, we want to analyze if the gains expressed in the literature remains, decrease or increase in presence of coordination, return variability and information sharing among the actors of the supply chain.

**4 - Product Recovery Decision-making in the Context of Internet of Things: A Review and Generic Roadmap to End-of-life Product Management**Xianghui (Richard) Peng, Penn State Erie, The Behrend College,  
Erie, PA, United States, Kai Meng, Ying Cao, Victor R. Prybutok

This research provides a state of the art review on End-of-Life (EOL) product recovery decision-making in the context of Internet of Things. We contextualize and apply an implementation framework to enable sustainable EOL product management based on enriched information. We also propose a generic roadmap for model and methodology selection to assist practitioners in making smart decisions.

## ■ WC33

North Bldg 222C

**Transportation-Operations**

Contributed Session

Chair: Yanshuo Sun, Florida State University, 2005 Levy Ave, Rm. 241  
MRB, Tallahassee, FL, 32310, United States**1 - Mothership and Drone Routing Problem with Obstacles**Stefan Poikonen, Assistant Professor, University of Colorado  
Denver, 1475 Lawrence Street, Denver, CO, 80202, United States,  
Bruce L. Golden

The Mothership and Drone Routing Problem with Obstacles extends previous work on the mothership and drone routing problem, which considers a tandem between a ship and a drone. The drone is required to visit each of a set of targets. However, the drone has finite battery life and, thus, must coordinate with the ship. In previous work, we utilized second order cone programming as an embedded procedure. However, the addition of obstacles (dry land, political boundaries, etc.) which the mothership is not allowed to penetrate creates non-convexity in the problem. We propose a solution method which forms an initial solution than iteratively improves it using sequential second order cone programming.

**2 - A Real-time Dynamic Model for Vehicle Routing Problem with Safety Criteria**Qiong Hu, Auburn, Auburn, AL, 36832, United States,  
Alexander Vinel

Driver's safety is an important issue in the transportation, especially for long-haul truck industrial. We consider vehicle routing problem to enable safety constraint in decision making. We developed a dynamic model based on the statistical result of estimating risk under real-time driving conditions such as weather and traffic. Our model is based on real-life data collected by combining different sources. As a first step, value iteration and breath-first-search have been applied in our model to provide the best policy for a driver to schedule stop during route to minimize risk.

**3 - Automatically Generating Shunting Operation Plan for District Local Train Based on Dynamic Programming**Li Li, Southwest Jiaotong University, Chengdu, China,  
Gongyuan Lu, Bojian Zhang

An LP model is proposed to describe the process of flat shunting operation and optimize the shunting operation plan for district local train, considering the initial and terminal status of cars on hand in the classification yard as the input variable. On the premise of ensuring the minimum number of coupling hooks, considering the use of shunting lines, the requirements of locomotive energy consumption, and the number of sliding hooks, to improve the marshaling efficiency and realize the operation plan's auto-generation for the station sequence marshaling mode district local train.

#### 4 - A Branch-and-price Algorithm for the Hitchcock-Koopmans Problem with Reusable Transportation Assets

Tulay Flamand, Assistant Professor, Colorado School of Mines, Division of Economics and Business, Engineering Hall 816 15th Street, Room 313, Golden, CO, 80401, United States, Mohamed Haouari, Ghaith Rabadi

We address a new variant of the Hitchcock-Koopmans problem that arises in commercial logistics where a given set of commodities must be transported from multiple supply nodes to multiple demand nodes using different types of transportation modes. Each transportation asset has a finite capacity and can be used for multiple consecutive rotations (i.e. round-trips). The problem requires delivering all commodities within a specified deadline while minimizing the total transportation cost. We describe an exact branch-and-price algorithm and present some preliminary computational experiments.

#### 5 - Nudging Commuters' Travel Choices with Dynamic and Personalized Incentives for Transportation Network Efficiency

Yanshuo Sun, Florida State University, Tallahassee, FL, United States, Lei Zhang

This paper explores an emerging strategy of transportation demand management, where dynamic and personalized incentives are transferred to travelers to influence their travel choices toward a more socially desirable state. A day-to-day traffic dynamics model is adopted, where commuters update their perceived travel time through trying and learning, based on which choices are made. A mathematical programming model is proposed for the system operator to design individually customized incentives daily. Through numerical analyses, we identify a paradox that increasing incentive limits do not necessarily improve the system efficiency due to probabilistic responses of travelers.

## ■ WC34

North Bldg 223

### Game Theory II

Contributed Session

Chair: Wei Wei, Waterloo University, Waterloo, ON, Canada

#### 1 - Differentiable Linear Tracing Procedures for Selecting Nash Equilibrium and its Refinements

Chuangyin Dang, Professor & Acting Head, City University of Hong Kong, 83 Tat Chee Avenue, Kowloon, Hong Kong

The selection of a unique Nash equilibrium and its refinements has always been a concern in game theory. Nevertheless, Harsanyi's linear tracing procedure can only select a unique Nash equilibrium for generic games. With the introduction of a differentiable quadratic function of an extra variable, this paper develops differentiable linear tracing procedures by incorporating concave quadratic terms into payoff functions. It is shown that the procedures are able to select, for every game, a unique Nash equilibrium, perfect equilibrium, proper equilibrium and perfect d-proper equilibrium, respectively. Numerical results further confirm the effectiveness and efficiency of the procedures.

#### 2 - A Game Theory Model for Resource Allocation in Large Systems Design

Soodabeh Yazdani, George Mason University, Takoma Park, MD, 20912, United States, Edward Huang

Engineering design is a concurrent process with multiple engineers designing different components of a system simultaneously under the supervision of a project manager. Project manager allocates limited resources needed for the design process among the different engineers trying to optimize the overall value of the whole system. However, each team has its private information about the characteristics of the component being designed and the goal of each team is usually misaligned to the objective of the project manager. The goal of this paper is to develop an efficient mechanism for allocating resources in large systems design.

#### 3 - Dynamic Decision Making with Asymmetric Information and Dependent States

Deepanshu Vasal, University of Texas, Austin, TX, United States

We consider finite horizon dynamic game with asymmetric information with  $N$  cooperative and selfish players where there exists an underlying state of the system that is a controlled Markov process, controlled by players' actions. In each period, a player makes a common observation of the state and a private observation, and gets an instantaneous reward which is a function of the state and everyone's actions. We present a sequential decomposition methodology to compute structured perfect Bayesian equilibria (SPBE) of this game, which computes SPBE in linear time. These equilibria exhibit signaling i.e. players' actions reveal part of their private information that is payoff relevant to other players.

#### 4 - Modeling a Biofuel Supply Chain as an Equilibrium Problem with Equilibrium Constraints (EPEC): A Policy Analysis

Saman Hamzeh, PhD Candidate, University of Wisconsin-Milwaukee, 3200 N. Cramer, Milwaukee, WI, 53211, United States

We consider a biofuel supply chain problem in which a farmer supplies downstream refineries with non-identical crops. The problem has been modeled as a multi-leader-single-follower game to derive the farmer's (follower) decisions on land use as well as refineries' (leaders) proposed prices to the farmer. We join the leaders' problem using EPEC formulation to find the NE. Parametric analyses are used to study the effect of subsidies on the profit of the players and the total social welfare of the supply chain. We observe that a government's expenditure can be offset by the increase of the social welfare under certain circumstances.

#### 5 - On the Smooth Pasting Principle and the Non-existence of Equilibrium Stopping Rules in Time Inconsistent Problems

Wei Wei, Postdoctoral Fellow, Waterloo University, Waterloo, ON, Canada, Xunyu Zhou, Ken Seng Tan

This paper considers a time inconsistent stopping problem. We show that properties of standard optimal stopping models may not be inherited when time consistency is lost. First, we focus on smooth pasting (SP). We find that the SP principle solves the time inconsistent problem within the intra-personal game theoretic framework if and only if a certain inequality is satisfied. Second, we formally show that the time inconsistent stopping problem does not admit any intra-personal equilibrium whenever the SP principle fails. The non-existence result and the failure of the SP principle caution blindly applying the SP principle to optimal stopping problems that are time inconsistent.

## ■ WC35

North Bldg 224A

### Aviation Economics

Sponsored: Aviation Applications

Sponsored Session

Chair: Farbod Farhadi, Roger Williams University, Bristol, RI, 02809, United States

#### 1 - Application of Random Utility Models for Airline Preference Estimation in Complex Operational Environment

Ivan Tereshchenko, University of California, Berkeley, CA, United States

Random utility models can be successfully applied to analyze decision-making strategies in settings when all decisions are made independently of each other. However, in air transportation, this is rarely the case. For example, aircraft operators make decisions about individual aircraft based on decisions made about all flights at their disposal. We use simulated schedules and optimization-based decision-making strategies to assess how well the random utility models can estimate parameters of airline objective functions in the realistic operational environment.

#### 2 - Two-stage Optimized Recommendation Model: An Empirical Study of Airline Marketing on Website Visits

Chen Zhang, UNSW, Sydney, Australia

Traditional recommendation system utilises users' historical purchases or browsing data to recommend products based on the similarity analysis, ignoring individual characteristics of the user and dynamic characteristics of the market. In this paper, we propose a new two-stage recommendation model using optimisation theory. The first stage uses AI algorithm to extract each individual user's preference feature. The second phase dynamically identifies users online intentions, dynamically adjusts recommended content, and provides personalised and optimised recommendations. The proposed model works better than the traditional recommendation model in the experiment.

#### 3 - A Data-Driven Analysis of Equilibrium in the U.S. Airline Market

Soheil Sibdari, University of Massachusetts, Brighton, MA, 02135, United States, Farbod Farhadi, David F. Pyke

When multiple firms exist in a market, game theory can be used to analytically model their interactions. In such analysis, the optimal solution is replaced by an equilibrium. In this paper, we address an equilibrium analysis in the U.S. airline market using a large transactional data set. We also characterize the equilibrium outcome of the game and address its existence and uniqueness using the data set. We provide conditions under which multiple equilibria can be achieved.



## ■ WC36

North Bldg 224B

**Inventory Management III**

Contributed Session

Chair: Stefan Minner, Technische Universitaat München, Munich, 80333, Germany

**1 - A Supply Planning and Inventory Management Problem for a Single Item with Random Demand and Substitutable Components**

Zehra Melis Teksan, Assistant Professor, Ozyegin University, Cekmekoy Kampusu Nisantepe Mah Orman Sk, Cekmekoy, Istanbul, 34794, Turkey, Joseph Geunes

We consider a supply planning and inventory management problem for an item within a single planning period with random demand. The production of the end-item requires a particular component whose supply availability depends on the price the producer offers to suppliers. The amount of supply and the production capacity are determined by the response of suppliers to the producer's price offer. The goal is to determine optimal supply pricing and production decisions when the component has a number of potential substitutes with different supply availabilities. We analyze the optimal supply-pricing policy with various pricing options, as well as policies when supplier-specific fixed charges exist.

**2 - An Inventory System with Reserved Stock**

Arnab Bisi, Johns Hopkins Carey Business School, 100 International Drive, Baltimore, MD, 21202, United States, Yanyi Xu, Maqbool Dada

We consider an infinite horizon periodic-review base stock inventory system with partial backorders and lost sales. For the long-run average cost problem, we determine structural properties of a proposed  $(k, R)$  policy and discuss how to find the optimal base stock  $R$  and reservation or holdback stock  $k$ . We also describe how two supply modes, of the type due to Barankin (1961), can be incorporated into our model by using a  $(k, Z, R)$  policy while generating further insights into the policy structure.

**3 - The Joint Replenishment Problem under Cycle Time Constraints**

Yu-Liang Lin, North Carolina State University, Raleigh, NC, 27606, United States, Chi-Yi Chen

The Joint Replenishment Problem (JRP) is to determine the replenishment cycle times of a group of items in single facility system over an infinite horizon. We investigated the JRP with cycle time constraints that are popular in inventory systems with restrictions such as max/min order quantity and storage capacity, etc. Based on the optimality structures, we categorize the items into four types and propose an efficient algorithm for solving this constrained JRP. Our random experiments demonstrate the proposed algorithm is effective as compared with the existing approaches in the literature.

**4 - Integrated Location-inventory Optimization in Slow Moving Spare Parts Networks Using Benders Decomposition**

Stefan Minner, Technical University of Munich, Munich, 80333, Germany, Patrick Zech, Zuo-Jun Max Shen

Virtual inventory sharing is an effective method to pool inventories in spare parts networks. We propose a novel location-inventory model which integrates strategic facility choice, tactical base-stock level setting and operational sourcing decisions. The mixed integer linear program combines a set-covering problem and a semi-Markov decision process. The model's special structure suggests Benders decomposition as an effective method to solve the problem. Numerical experiments confirm the efficiency of Benders decomposition and emphasize the value of an integrated model compared to a sequential location first, inventory and sourcing second approach.

## ■ WC37

North Bldg 225A

**Applied Probability and Simulation**

Sponsored: Applied Probability

Sponsored Session

Chair: Sandeep Juneja, Tata Institute of Fundamental Research, Mumbai, 400005, India

**1 - An Asymptotically Optimal Index Policy for the Finite Horizon Restless Bandit**

Peter Frazier, Cornell, Weici Hu

We consider the restless bandit, a generalization of the multi-armed bandit in which arms may change state when they are not pulled. In the stochastic infinite-horizon setting, Whittle proposed the Whittle index policy and conjectured the per-arm optimality gap vanishes as the number of arms grows to infinity while holding fixed the fraction of arms that can be pulled per period. Weber and Weiss showed this conjecture is true when arms have only 3 states, or when the fluid limit has a globally stable equilibrium point. We propose a novel but related index policy for the finite-horizon setting, and show it is asymptotically optimal in the same sense without restrictions on the fluid limit.

**2 - Weighted Stochastic Approximation for Large-scale Network Computation**

Jingchen Liu, Columbia University, Department of Statistics, 1255 Amsterdam Avenue, New York, NY, 10027, United States, Xueying Tang, Zhi Wang

We consider the parameter estimation and computation via stochastic approximation for large-scale multi-relational network and propose a weighted sampling scheme biased towards observations with more information regarding the parameters. It is shown to be computationally more efficient if the weights are properly chosen. Besides the computational efficiency, the biased scheme is observed to contribute to the estimation quality and substantially improves the out of sample prediction performance.

**3 - Credit Risk: Closed Form Approximate Maximum Likelihood Estimation and Fast Simulation**

Anand Deo, Tata Institute of Fundamental Research, Homi Bhabha Road, Navy Nagar, Colaba, Mumbai, India, Sandeep Juneja

We consider discrete default intensity based and logit type reduced form models for conditional default probabilities for corporate loans where we develop simple closed form approximations to the maximum likelihood estimator (MLE) when the underlying covariates follow a stationary Gaussian process. In a practically reasonable asymptotic regime where the default probabilities are small, the number of firms and the time period of data available is reasonably large, show that the proposed estimator behaves similarly to the MLE. We also derive large deviations asymptotics for large losses. These have interesting geometric properties, which we exploit to develop efficient simulation techniques.

**4 - Efficient Rare-event Probability Computation of Functional Exceedance**

Raghu Pasupathy, Purdue University, West Lafayette, IN, 47907, United States

We present methods for efficiently calculating the probability of the function  $f$  of an elliptical random vector  $X$  exceeding a given threshold. Elliptical random vectors are general in that they subsume a variety of random vectors that are commonly in use, e.g. multivariate normal, multivariate  $T$ , and multivariate logistic. The proposed method uses importance sampling and actively exploits the local structure of  $f$  to construct estimators that exhibit bounded relative error. We discuss extensions to functions of appropriate stochastic processes.

## ■ WC40

North Bldg 226B

**Combinatorial Optimization**

Contributed Session

Chair: Hadi Farhangi, Savannah State University, Savannah, GA, United States

**1 - Client Selection for a Risk-sensitive Commodity Options Underwriter with Poisson Demand**

Belleh Fontem, University of Mary Washington, Fredericksburg, VA, 22407, United States, Megan Price

We consider a maximization problem for a risk-sensitive underwriter of an option contract on a commodity with geometric Brownian motion spot price trajectories. Firms hoping to enter into service agreement with the underwriter each face Poisson demands that are the underwriter's responsibility to satisfy. While considering payoff risk, the underwriter aims to select the optimal combination of client firms to privilege with its option contract. Using payoff variance as our risk measure, we derive for a special case, the optimal solution algorithm for the variance-constrained maximization problem. Results from the special case analysis inspire the design of two heuristics for the general case.

**2 - An Evolutionary Approach to Constrained Many-objective Combinatorial Optimization**

Hayrullah Mert Sahinkoc, Bogazici University, Istanbul, Turkey, Umit Bilge

Many-objective optimization tries to characterize and overcome the challenges posed by the high number of objectives. Most of the existing studies work on well-defined continuous mathematical functions with designed Pareto front characteristics whereas combinatorial and constrained problems are rarely addressed. Many-objective 0-1 knapsack problem with multiple constraints is chosen in our study and our proposed algorithm combines the effective features of the existing many-objective approaches with several other prominent evolutionary strategies in an innovative fashion. Numerical results show the success of the proposed algorithm compared to some existing approaches.

### 3 - Time Space Combinatorial Optimization Problems and Applications

Hadi Farhangi, Visiting Assistant Professor, Savannah State University, 204, 3219 College Street, 3219 College Street, Savannah, GA, 31404, United States

This work presents a time extension of some of the combinatorial optimization problems. Particularly, the variables are redefined to include time into the problem. The resulting models are disjoint combinatorial problems that can be connected using coupling constraints. The properties of these problems and appropriate solution methods are presented in this work. Finally, some applications of the time space combinatorial problems are discussed.

## ■ WC42

North Bldg 227A

### Practice- Simulation I

Contributed Session

Chair: Matthew J. Saltzman, Clemson University, Dept of Mathematical Sciences, Martin Hall Box 340975, Clemson, SC, 29634-0975, United States

#### 1 - GPU Supported Large Scale Simulation Models for Influenza Pandemic Outbreaks

Shalome Hanisha Anand Tatapudi, University of South Florida, 4202 E. Fowler Avenue, ENB 118, Tampa, FL, 33620-5350, United States, Zhila Nouri, Tapas K. Das

Influenza pandemics are a serious concern and researchers are trying to understand its patterns. One such tool to effectively understand the disease characteristics is through an agent-based (AB) simulation model, which is versatile, yet has computational limitations when it comes to simulating larger populations. This study integrates the flexibility of AB simulation with computational efficiency of a graphical processing unit (GPU) to create models for pandemic outbreaks in large areas comprising of hundreds of millions of people.

#### 2 - Comparison of MRSA Infection Control Policies in ED Patients

Karthick Srinivasan, Rochester Institute of Technology, Rochester, NY, 14623, United States, Vignesh Krishnan Rajkumar, Levi Toweh, Nasibeh Azadeh Fard

Methicillin-Resistant *Staphylococcus Aureus* (MRSA) is a major cause of preventable nosocomial infections in ED. The changes made in admission policies of patients with MRSA can affect patient throughput in hospitals. In this research, we study the impact of admission policy change for MRSA patients in an ED of a large hospital in upstate NY using discrete-event simulation modeling.

#### 3 - An Agent-based Model of Subsidized Flooding Insurance

Valerie Washington, University of Michigan, Ann Arbor, MI, 48109, United States

Flood insurance is one strategy for addressing the economic impact of floods to both homeowners and their community. In this paper, I use agent-based modelling to explore how income-based subsidies influence mitigation strategies employed by agents, and whether that includes large-scale abandonment. I investigate the effect of subsidized and unsubsidized flood insurance on community mitigation decisions, damages incurred, and vacancy and move out rates. Damages are evaluated from the perspective of individual homeowners and the community at large.

#### 4 - Review and Analysis of Airplane Boarding Strategies Based on Discrete Events Simulation

Alejandro Garcia del Valle, Professor, University of A. Coruna, Escuela Politecnica Superior, C/ Mendizabal S/N - Esteiro, A. Coruna, 15403, Spain, Roi Sanchez-Tutor, Diego Crespo-Pereira, Javier Faulin

Airport taxes are one of the most critical economic factors for an airline due to the time the plane stays on the airport while turn-around. Boarding is a key part of turn-around for both customer satisfaction and airline profitability. This is the reason why so many strategies have been designed in order to reduce boarding times. By using Discrete Event Simulation, different boarding strategies are analyzed to determine which one is more efficient in Boeing 737-800 according to different scenarios considering plane occupation, delays and 2-door boarding.

#### 5 - What Not to Expect When You're Expecting:

##### Perils of Sampling and Estimating for Lognormal Distributions

Matthew J. Saltzman, Associate Professor, Clemson University, Dept of Mathematical Sciences, Martin Hall Box 340975, Clemson, SC, 29634-0975, United States, William C. Bridges, Neil J. Calkin

Lognormal distributions can be problematic when the variance of the underlying normal distribution is other than very small. We illustrate these problems in terms of sampling issues, interval estimation of the mean, and comparison of lognormal and logbinomial distributions with similar means and variances.

## ■ WC43

North Bldg 227B

### NREL Session

Emerging Topic: Energy and Climate

Emerging Topic Session

Chair: Brady Stoll, National Renewable Energy Laboratory, CO, United States

#### 1 - Modeling Challenges of High Photovoltaic Penetrations in Future Electric Grids

Brady Stoll, NREL, 15013 Denver West Parkway, Golden, CO, 80401, United States, Elaine Thompson Hale, Jennie Jorgenson

As states and utilities incentivize low carbon electricity and the cost of solar photovoltaics (PV) drop, it is likely PV penetrations will continue to increase. We utilized a capacity expansion model, the Resource Planning Model, to study the impacts of high solar penetrations in the western United States through 2035. We here describe the creation of high solar penetration scenarios and operational improvements needed to accurately model these scenarios, including updated operating reserve requirements and curtailment requirements. Additionally, we present our findings on the increased operability of the system in 2035 when these modeling improvements were included.

#### 2 - Late-century Electric Sector Climate Impacts Using a High-resolution Capacity Expansion Model

Stuart Cohen, National Renewable Energy Laboratory, 15013 Denver West Parkway, RSF 300, Golden, CO, 80401, United States

Climate impacts on the electric sector will vary in space and time while also being influenced by market and policy evolution. I'll discuss how the National Renewable Energy Laboratory's ReEDS model of U.S. electric sector expansion is being used to examine climate impacts on load, system performance, and water resources while accounting for regional, diurnal, and seasonal differences; technology-specific responses; and market-policy developments. ReEDS has recently been modified to solve through the year 2100, enabling this presentation to explore climate impacts in the mid-to-late century within the context of highly uncertain human and natural system development.

#### 3 - Deep Reinforcement Learning for Urban Energy Management and Demand Response

Jose Vazquez Canteli, University of Texas at Austin, Austin, TX, United States

The increasing amount of sensor data from buildings can help improve the energy management in urban settings. Reinforcement learning (RL) is a self-tuning and model-free controller that learns from real-time and historical data. RL is scalable and attractive for demand response in residential buildings. We developed CityLearn, a simulation environment based on CitySim, an urban energy simulator, and TensorFlow, a library that allows implementations of machine learning algorithms. We applied CityLearn in a case study with multiple buildings, controlled by RL, that compete against each other to reduce their cost of electricity, which increases when they consume electricity simultaneously.

## ■ WC44

North Bldg 227C

### Models and Optimization Methods for Future Electricity Markets

Sponsored: Energy, Natural Res & the Environment/Electricity

Sponsored Session

Chair: Mahnoosh Alizadeh

#### 1 - Competitive Market with Renewable Power Producers Achieves Asymptotic Social Efficiency

Yue Zhao, Stony Brook University, 127 Light Engineering, Stony Brook, NY, 11794, United States

A price-making two-settlement power market in which both conventional generators and renewable power producers (RPPs) participate is studied. It is proved that the Nash Equilibrium (NE) of the market converges to the social optimum as the number of RPPs increases. As a result, social efficiency is asymptotically achieved with a simple market mechanism for integrating RPPs, without the need for an independent system operator to perform a centralized stochastic optimization. The analytical derivation of the NE offers an elegant characterization of the market power of the competitive RPPs. The market outcomes predicted by the developed theoretical results are demonstrated by simulation studies.

**2 - Renewable Scenario Generation using Adversarial Networks**

Baosen Zhang, University of Washington, Yize Chen, Wang Yishen, Daniel Kirschen

Scenario generation is an important step in the operation and planning of power systems. In this talk, we present a data-driven approach for scenario generation using the popular generative adversarial networks, where deep neural networks are used in tandem. Compared with existing methods that are often hard to scale or sample from, our method is easy to train, robust, and captures both spatial and temporal patterns in renewable generation. In addition, we show that different conditional information can be embedded in the framework. Because of the feedforward nature of the neural networks, scenarios can be generated extremely efficiently.

**3 - Pricing Differentiated Services in Electric Vehicle Public Charging Station Networks**

Mahnoosh Alizadeh, University of California-Santa Barbara, Santa Barbara, CA, United States, Ahmadrza Moradipari

We study the pricing problem of an electric vehicle charging network operator (CNO) offering differentiated access plans to its stations. We consider a scheme where users cannot directly choose which station to use when charging their vehicles. Instead, they are routed by the CNO to different stations with heterogeneous wait times and amenities based on their service plan. We design incentive compatible pricing-routing policies that take into account the heterogeneous energy needs of users, their value of time, travel plans, as well as locationally-variant prices of electricity and station capacities.

**4 - Dynamic Power Distribution System Management with a Locally Connected Communication Network**

Hao Zhu, The University of Texas at Austin, 2501 Speedway, Austin, TX, 78712, United States, Kaiqing Zhang, Wei Shi

Coordinated optimization of distributed energy resources (DERs) is a key distribution system management (DSM) problem. Two challenges exist therein: i) the possibly disconnected communication network; and ii) the system dynamics from the variable DERs/loads and measurement error. This talk will present the modeling and algorithm design for DSM by addressing these two concerns. First, a game-theoretic characterization is proposed to account for a locally connected communication network with Nash equilibrium analysis. Second, a projected-gradient based asynchronous DSM algorithm is developed for distributed equilibrium learning, with its convergence speed and tracking error analyzed.

**5 - Car and Ride Sharing Platforms with Electric Vehicle Fleets**

Subhmesh Bose, University of Illinois-Urbana Champaign, 306 N. Wright Street, 4058 ECE Building, Urbana, IL, 61801, United States

Shared usage and electrification in urban transit systems are on the rise. Motivated by that trend, we analyze the business model of car sharing services such as Autolib' and ride sharing services such as Uber with an electrified car fleet. Electric vehicles (EVs) impact the operation of such platforms in two ways. First, battery charging considerations affect waiting times for customers, driver's willingness to accept rides, etc., and influence the revenues from transit services. Second, plugged-in EVs can garner revenues by utilizing their batteries to provide grid services. We employ a queueing theoretic framework to study the impact of these factors on pricing policies of such platforms.

**WC45**

North Bldg 228A

**Practice- Electrical Markets**

Contributed Session

Chair: Srinivasa Prasanna, Electronics City, Opposite Infosys Technologies, Bangalore, 560100, India

**1 - Using Python to Decompose Reduced Costs for a Capacity Expansion Model of the Electric Power Sector**

Kelly Eurek, National Renewable Energy Laboratory, 15013 Denver W. Pkwy, Golden, CO, 80401, United States

The Regional Energy Deployment System (ReEDS) is a capacity expansion model that identifies least-cost solutions to build and operate the US electric power grid. ReEDS is formulated as a linear program and written in GAMS. To understand the decision making in ReEDS, we designed a Python tool to harvest data from the MPS and GAMS solution files to reconstruct the reduced costs of the decision variables. Examining reduced costs allows us to calculate the cost and value streams of supply-side technologies and compare which options recover costs versus those that do not. This Python tool helps to identify errors in the model, provides solution transparency, and can be applied to other models written in GAMS.

**2 - Implement Real Time Pricing with Multiarmed Bandit Games**

Andrew Lu Liu, Associate Professor, Purdue University, 315 North Grant Street, School of Industrial Engineering, West Lafayette, IN, 47907, United States, Zibo Zhao

The situation where price-responsive consumers determine what to do in the near future (such as when to charge their PEVs) forms a dynamic and incomplete-information game, in which the consumers' collective actions will impact electricity prices, which in turn affect their payoffs. We propose a multiarmed bandit (MAB) game framework in which each consumer plays an MAB problem to minimize the cumulative regret, as opposed to naively responding to day-ahead prices. Numerical results show very fast convergence to a steady-state of the MAB game with much reduced price volatility and lower transmission congestion costs than the naive-response case.

**3 - Market Design and Competition in Short Term Electricity Markets - Lessons Learned from a Stochastic Multistage Energy System Model**

Frieder Borggrefe, German Aerospace Center (DLR), Pfaffenwald Ring 38-40, Stuttgart, 70563, Germany

This paper provides results from an integrated model for short-term electricity markets, including day-ahead, intraday and balancing markets. Coping with volatile renewable feed-in is a key challenge to the future European electricity system. The paper shows first results from a stochastic linear commitment and dispatch model. Aim of the model is to analyze how trading in the short-term markets will change with increasing shares of renewable energies. The model results are part of the BEAM-ME project: This project develops speed-up methods and applies models to high performance computing (HPC). The paper discusses the next steps to expand the model and challenges when applying the model to HPC.

**4 - Community Market Design for Unlocking Congested Distributed Energy Operations**

Jesus Nieto-Martin, Senior Research Fellow, London Business School, Sussex Place, Regent's Park, London, NW1 4SA, United Kingdom, Derek W. Bunn

This study is motivated by the Orkney Archipelago in Scotland, which presents a substantial amount of renewables connected to undersized infrastructure and is only linked to the Scottish mainland by two 33kV submarine cables. Currently, there is a curtailment mechanism based on the Last-In-First-Out (LIFO) principle. This study provides a market-based alternative to improve current operations by decreasing the curtailment of wind generators. This is achieved through participation into a Blockchain-based Community Local balancing market among islands, unlocking demand side response actions among them and increasing their trading opportunities.

**5 - Handling Optimization in Large Scale Energy Management with Hierarchical Approach**

Srinivasa Prasanna GN, Professor, IIITB, Bangalore, India, Sunil K. Vuppala

We present optimization methods of energy management in large scale smart grid systems. We handle violated coupling constraints in a hierarchical approach.

We present three cases covering different possibilities of feasibility in the hierarchical approach and techniques to handle the infeasibility. We compare our results with non-hierarchical and a proposed All-or-None heuristic.

**WC46**

North Bldg 228B

**Sustainable Development of Food, Water, and Energy Resources**

Sponsored: Energy, Natural Res & the Environment/Energy

Sponsored Session

Chair: Yao Zhao, Rutgers University, Newark, NJ, 07102-1895, United States

Co-Chair: Kwon Gi Mun, Fairleigh Dickinson University, Teaneck, NJ, United States

**1 - Designing Wastewater Supply Chains for Riparian Developing States**

Jiyong Eom, KAIST College of Business, 85 Hoegi-ro, Dongdaemun-gu, Seoul, 130-722, Korea, Republic of, Kwon Gi Mun, Yao Zhao

Designing wastewater supply chains for riparian states has become a highly controversial policy issue because of their asymmetric externality relationships and vulnerability positions. The problem is particularly pronounced in low-income countries facing tight public budgets and development uncertainties. We develop the concept of wastewater management for riparian states by proposing a spatially, temporally, and technologically explicit optimization model. A policy guidance for designing wastewater supply chains is provided for the case of Ganga river management in India.



## 2 - Designing Hydro Supply Chains for Energy, Food, and Flood

Kwon Gi Mun, Ph.D, Fairleigh Dickinson University, Teaneck, NJ, United States, Yao Zhao, Raza Ali Rafique

The interconnected issues such as Water, Food, Energy and Flood are among the most formidable challenges faced by developing countries. In this paper, we apply SCM concepts to water resource development and provide the end-to-end and dynamic perspectives. We found that the development of hydropower has the potential to address all these issues simultaneously. Our results demonstrate the value of the SCM perspective on hydro network expansion, and provide insights on the optimal development strategies regarding location, sequence and mix of hydro projects.

## 3 - Fiscal Policy in the Natural Gas Sector: An Optimization Approach

Ekaterina Dukhanina, MINES ParisTech, 60 Boulevard Saint Michel, Paris, 75006, France, Olivier MASSOL, Daria Kirova

In this paper we analyze the results of introduction of a new formula for mineral resource extraction tax in the biggest and the most complex domestic natural gas market. We build an economic equilibrium model involving strategic interaction between major natural gas producers and government subject to operational, political and market constraints, specific for the Russian gas industry. We show that the new tax is neither an optimal policy for the tax revenue maximization nor a socially optimal solution, as the possibility of sequential optimization distorted initial results of the tax reform.

## WC47

North Bldg 229A

### Practice- Sustainable Operations

Contributed Session

Chair: Qiangfei Chai, Xi'an Jiaotong University, Xi'an, 2, China

#### 1 - A Performance Measurement System for Green Supply Chain Performance Evaluation

Nima Kazemi, Massachusetts Institute of Technology, Cambridge, MA, 02140, United States, S. Maryam Masoumikh

In this paper, a fuzzy-rule based performance measurement system is developed to evaluate the performance measures for both Green supply chain management practices implementation and performance outcomes. To construct the performance measurement system, a comprehensive literature review was conducted to investigate various green supply chain initiatives. Structural equation modeling is used to categorize measures and then a fuzzy membership function is designed for evaluation purpose. The applicability of the developed performance measurement system is evaluated by using a real case study in Malaysian manufacturing industry.

#### 2 - An Analysis of Sustainability in Small Businesses in New York

John Vongas, Ithaca College, Ithaca, NY, United States, Narges Kasiri, Hormoz Movassaghi, Daniel Ruthman

Small and Medium-sized Enterprises (SMEs) are responsible for most of the pollution generated by businesses on earth; they are collectively generate approximately 60% of total carbon dioxide emissions and an alarming 70% of total pollution. Regulations, social and competitor trends, education and businesses' self-motivation are among the major factors behind the small businesses' decision on implementing sustainability in their operations. We examine the data collected from hundreds of SMEs in NY State to identify the motivators and obstacles to the adoption of sustainable solutions by SMEs in NY State.

#### 3 - Optimal Carbon Abatement Strategy Under Cap-and-trade

Qiangfei Chai, Xi'an Jiaotong University, Xi'an, China, Zhongdong Xiao

The importance of carbon abatement has been frequently emphasized around the world. This paper attempts to explore the appropriate carbon abatement strategy for firms who are regulated by cap-and-trade by taking into account the unique advantages of remanufacturing for both the monopolistic environment and the competitive environment. Our results indicate that involving in investment and remanufacturing collectively strategy is the optimal strategy in the monopolistic environment. However, this strategy is no longer optimal for the manufacturer in the competitive environment. We provide some decision guidance for the firms in the competitive environment.

## WC48

North Bldg 229B

### Environment, Energy, and Natural Resources

Contributed Session

Chair: Kenneth Bruninx, KU Leuven, Celestijnenlaan 300, Leuven, B3001, Belgium

#### 1 - On the Interaction between Aggregators, Electricity Markets and Residential Demand Response Providers

Kenneth Bruninx, Postdoctoral Researcher, KU Leuven, Celestijnenlaan 300, P.O. Box 2421, Leuven, B3001, Belgium, Hrvoje Pandzic, Helene Le Cadre, Erik Delarue

The flexibility of thermostatically controlled loads may be monetized by aggregators, acting as mediators between consumers and the electricity market. We study the strategic interactions between an aggregator, its consumers and the wholesale market using a bilevel optimization model. The aggregator-consumer interaction is captured as a Stackelberg or a Nash Bargaining Game. The aggregator takes strategic positions in the day-ahead electricity market, represented as a stochastic Stackelberg Game. The presented methodology may be used to assess the value of DR in a deregulated power system.

#### 2 - Failure of Green Technology Adoption and the Decision to Offshore Production

Wenqing Zhang, University of Minnesota Duluth, 1318 Kirby Drive, Labovitz School of Business and Economics, Duluth, MN, 55812, United States, Prasad Padmanabhan, Chia-Hsing Huang

Strong environmental pollution regulations in host countries (for example, through carbon taxes, focus on the triple bottom line, incentives to select green technology investment options) have forced multinational corporations (MNCs) to change their operations practices. In this study, an optimization model is presented where a domestic firms' propensity to offshore is shown to be function of the failure of green technology adoption. The findings suggest that a domestic firms' propensity to offshore pollution via production in pollution friendly host countries is directly related to the possibility of failure of the adopted green technology.

#### 3 - Scenario Selection and Weighting Algorithm for Large Scale Stochastic Mixed-integer Programs and Application to Stochastic Transmission Planning

Jesse Bukenberger, Pennsylvania State University, 310 Leonhard Building, University Park, PA, 16802, United States, Mort David Webster, Uday Shanbhag

Stochastic programs with many scenarios and complex recourse decisions can exceed computational memory and time resources. Often, the recourse costs of state-action pairs are not completely independent and exhibit a relationship that can be exploited with data compression techniques. We present an algorithm to select and weight a small subset of the original scenario space and feasible solution space to provide an efficient approximation of the costs of other state-action pairs. We demonstrate substantial computational savings in the context of stochastic transmission expansion planning.

#### 4 - Emission Reduction at Ports by Integrating Tax and Incentive Policies and Green Infrastructure Development

Anahita Molavi, University of Houston, 4722 Calhoun Rd, Houston, TX, 77204-4007, United States, Gino J. Lim

Air pollution due to port activities and development has a high impact on climate change and human health. However, ports are reluctant to implement emission abatement solutions due to associated barriers and costs. We analyze the process in which government defines incentive and tax policies and motivates ports to initiate green efforts. We develop a multi-objective bi-level programming model to find the optimal incentive and tax policies for the government in the upper level, and the optimal choice of green technologies for the multiple ports in the lower level.

#### 5 - A Bilevel Optimization Approach to Co-operative Dispatch of Transmission-level Renewables with Microgrids

Jialin Liu, 325 Riley Robb Hall, Ithaca, United States, Lindsay Anderson

As energy systems evolve to a sustainable and decentralized structure with a high penetration of renewable energy and distributed generation, microgrids (MG) will play a critical role, featuring distributed local generation, energy storage, and demand response. With the possibility of numerous MGs connected to and exchanging power with the transmission system (TS), new operational paradigms are required. Co-optimization of these systems will provide maximal benefits to the complete system. In this work, a bi-level optimization framework is used to model co-operative dispatch of TS and MG, and analyze the impacts on renewable penetration level, and the operation cost of both systems.

## ■ WC49

North Bldg 230

**Energy Policy and Planning III**

Contributed Session

Chair: Cristiana L. Lara, Carnegie Mellon University, 238 46th Street, Pittsburgh, PA, 15201, United States

### 1 - Joint Benefit of Transmission Switching, Siting, and Sizing of Energy Storages in Power Systems

Meltem Peker, Research Fellow, Bilkent University, Department of Industrial Eng, Ankara, Turkey, Ayse Selin Kocaman, Bahar Kara

This study discusses the joint benefits of transmission switching and other control mechanisms such as energy storage systems, demand side management and renewable energy curtailment for using clean sources in electricity generation without endangering the system. We analyze the effect of transmission switching on the total investment and operational costs, siting and sizing decisions of energy storage systems, and changes in the load-shedding and renewable energy curtailment amounts by using an extensive computational study.

### 2 - Undetectable Cyber Physical Attacks on Power Grids under the AC Model

Mauro Escobar, Columbia University, New York, NY, 10027, United States, Daniel Bienstock

We describe an algorithm for computing undetectable cyber-physical attacks on power grids under the AC power flow model. An adversary attacks a small set of nodes of the network: it can modify their demands as well as hide the signals that are measured (voltage and current). These actions are calculated so as to hide the underlying truth, which includes severe equipment overloads, while remaining consistent (i.e. not noticed) from the perspective of the control center of the system. On a second stage, we provide a mechanism to detect the attacked zone. We provide an algorithm and run experiments on large grids.

### 3 - Triple-bottom-line Approach to Optimizing Electricity Demand Response Schemes Using Smart Meter Data

Amir-Behzad Samii, Professor, Vlerick Business School, Bolwerklaan 21, Brussels, 1210, Belgium, Olga Varganova

Electricity Demand Response (DR) schemes impact people, planet, and profit. They can help low income consumers benefit from low cost of tariffs during the off-peak hours; reduce CO2 emissions by shifting the load to hours that solar and wind contribute more to power generation; and elongate the life of electricity distribution assets by reducing the peak-hour shocks. We use a three-objective optimization model to estimate the optimum relocation of consumption loads during off-peak/shoulder/peak hours. We analyze smart meter data supplied by Eandis-Belgium to estimate model parameters and provide decision makers with Pareto-efficient solutions utilized in power distribution command centers.

### 4 - Policy Making for Microgrid Planning to Reduce Emission

Aida Khayatian, University of Houston, Houston, TX, United States, Masoud Barati, Gino J. Lim

Integrated resource planning is intended to appraise new energy resources that examine a full spectrum of alternatives to enhance power system. The competitiveness of power investors, environmental issues, and reliability are challenges faced by power system planners. Future load growth, power output, and power outage in the face of uncertainty are other obstacles. This study integrates microgrid (MG) designing and expansion planning with generation and transmission planning to study the potential advantages of MG. Some performance indices are proposed to establish policy. The case studies illustrate the application of proposed model and policy.

### 5 - Stochastic Dual Dynamic Integer Programming for Electric Power Infrastructure Planning

Cristiana L. Lara, Carnegie Mellon University, Pittsburgh, PA, 15213, United States, Benjamin Omell, David Miller, Ignacio E. Grossmann

We address the long-term planning of electric power infrastructure under uncertainty. We propose a multi-stage stochastic integer programming formulation that optimizes the generation expansion to meet the projected electricity demand over few decades while considering detailed operational constraints, intermittency of renewable generation, power flow between regions, and load demand uncertainty. To solve the large-scale model, we decompose the problem using Stochastic Dual Dynamic Integer Programming (SDDIP), incorporate scenario sampling, and solve in parallel nodes within the same stage. We report results for the region managed by the Electric Reliability Council of Texas.

## ■ WC50

North Bldg 231A

**Retail Management**

Contributed Session

Chair: Armagan Bayram, University of Michigan Dearborn, Livonia, MI, 48152, United States

### 1 - Channel Transparency and Omnichannel Retailing: The Impact of Sharing Retail Store Inventory Availability with Online Shoppers

Xinyi Ren, University of Maryland, 3330 Van Munching Hall, College Park, MD, 20742, United States, Philip Evers

This paper empirically examines the effects of sharing retail store inventory availability with online shoppers at both the marketing and reverse logistics interfaces. Specifically, industry data is collected from a leading North American retailer to answer the following research questions 1. How does sharing brick-and-mortar inventory availability affect customer purchasing decisions at online and offline channels? 2. How does this policy affect customer conversion rates at the online and offline channels and the operational costs associated with product returns? Furthermore, the implications of these findings on inventory management are discussed.

### 2 - Food Waste in Online versus Offline Grocery Shopping

Alwin Dsouza, Arizona State University, 6459 S. Essex, Mesa, AZ, 85212, United States, Lauren Chenarides, Timothy Richards

U.S. households are responsible for a significant portion of food waste, which results when shoppers are unable to match purchases to expected consumption. Using multichannel store scanner data, this study investigates how the amount of food waste varies across online, offline and mixed shoppers. While online shoppers are more inclined to follow a shopping list, online shoppers are often required to pay a delivery fee and follow a minimum basket size. We use a model of consumer learning and inventory behavior to explore these two opposing effects and their impact on household-level food waste.

### 3 - A Model for Fresh Produce to Jointly Optimize Shelf Space Allocation, Inventory, and Pricing Decisions

Hasmukh Gajjar, Associate Professor, Indian Institute of Management Indore, Faculty Office #C-208, IIM Indore, Prabhindh Shikhar, Rau-Pithampur Road, Indore, India, Bhavin J. Shah

Fresh produce's demand primarily depends on its displayed stock, freshness and price. We present a model to jointly arrive at shelf space allocation, inventory and pricing decisions. Numerical results and sensitivity analysis are carried out to test the usefulness of the model.

### 4 - Direct and Wholesale Price Optimization in Omnichannel Environment Using Bilevel Optimization Model

Vishal Gupta, Indian Institute of Technology-Kharagpur, Department of Industrial & Systems Enggn., I. I T. Kharagpur, Kharagpur, 721302, India, Shrinath Dakare, Manoj Kumar Tiwari

We considered multi-period price optimization problem for a manufacturer (leader), also having a direct channel, and a multi-location multi-channel retailer (follower). Both manufacturer and retailer try to maximize their profits; moreover, manufacturer tries to increase the market share of their product. Assuming price and delivery lead time dependent attraction function, location-based holding and fulfillment costs, we propose a bilevel model that has a multi-objective upper level and single objective lower level. In the resulting omnichannel environment, we demonstrate how the model is effective in setting wholesale and direct channel prices using intelligent search heuristic.

### 5 - Dynamic Pricing Under Customer Review Effect

Ruizhi Shi, University of Minnesota, 1400 S. 2nd St, Minneapolis, MN, 55454, United States

In this talk, we consider a monopolist selling a single product to a sequence of customers. Each customer will make a purchase decision base on the current review and the price. If a customer purchases the product, he will post a review, which is drawn from a normal distribution centered at the true quality  $q$ . Only the seller knows the true quality therefore the customers have to use the review as an estimation of the true quality. We derive the optimal policy on how the seller should adjust the price to maximize the expected revenue. We also derive upper bounds on the best performance of any policy.

### 6 - Order Fulfillment Policies for Ship from Store Implementation in Omni Channel Retailing

Armagan Bayram, Assistant Professor, University of Michigan-Dearborn, 4901 Evergreen Road, Dearborn, MI, 48128, United States, Bahriye Cesaret

We consider an omni-channel retailer having both online and store operations and implementing ship-from-store fulfillment model. In this model, store orders are fulfilled from store inventories, but for an online order, the retailer can ship it either from the online distribution center or from any store location that maximizes its overall profit. We investigate dynamic fulfillment decisions: from which location to fulfill an online order when it arrives. We incorporate the uncertainty both in demand and in the cost of shipment to individual customers. We develop a stochastic dynamic framework and present our analytical and numerical findings on optimal fulfillment strategies.

## ■ WC51

North Bldg 231B

### Practice-Scheduling

Contributed Session

Chair: Leonardo Bedoya-Valencia, Colorado State University-Pueblo, 4702 Desert Candle Drive, Pueblo, CO, 81001, United States

#### 1 - A New Extension of the MSRCPS in a Resource Reallocation Context

Zhentao Hu, Huazhong University of Science & Technology, School of Management, HUST, Hongshan District, Wuhan City, Wuhan, 430074, China, Nanfang Cui

In this research, we proposed a new strategy to optimize MSRCPS, which expands the problem into a new one named RP-MSRCPS. For solving the new problem, a heuristic, which is a PSS procedure consisting of activity priority rule, dynamic weight-based resource priority rule, Hungarian method and 0-1 programming, is developed. The results of experiment on 1440 instances show that the new strategy is effective and the heuristic is efficient and robust in solving both the new and the previous scheduling problems.

#### 2 - Aircraft Maintenance Planning: Moving A-check Tasks to Line Maintenance

Qichen Deng, PhD Student, Delft University of Technology, Kluyverweg 1, Delft, 2629 HS, Netherlands, Bruno F. Santos, Daniel Coolen

In this study, we present a two-stage optimization model to minimize the total delay of maintenance tasks. It is for the first time to propose to move the A-check tasks from hangar to line maintenance. The model of first-stage is task planning, which groups the A-check tasks into packages and shifts them to line maintenance. The model of second-stage is task scheduling. It minimizes the total amount of delay given a task package. The proposed model is evaluated on a fleet of 30 aircraft. The results show that by task planning and scheduling, it can save up to 18% of aircraft downtime per A-check. Allowing performing tasks 4-14 days earlier than the desired dates can reduce the total delay of tasks up to 66%.

#### 3 - Stochastic Single-machine Scheduling with Learning

Haitao Li, Associate Professor, Univ. of Missouri-St Louis, College of Business Administration, 208 Express Script Hall, St Louis, MO, 63121-4400, United States

Learning is ubiquitous in the modern scheduling environment. While deterministic scheduling with known processing time and learning rate have been extensively studied, limited work exists to address the problems with both learning effect and uncertainty. In this talk, I introduce the single-machine scheduling problem with random nominal processing time and/or random job-based learning rate with both theoretical and computational results.

#### 4 - A Sequential Stochastic Mixed Integer Programming Model for Tactical Master Surgery Scheduling

Ashwani Kumar, PhD Candidate, The University of Melbourne, Peter Hall Building, Parkville Campus, Melbourne, 3010, Australia, Alysso M. Costa, Mark Fackrell, Peter G. Taylor

In this talk, we present a MIP model to optimise master surgery schedule (MSS) under downstream capacity constraints. We optimised the process over several scheduling periods, and we used various scenario realisations to model the uncertainty. Our model had novelty that it used scenarios in chronologically sequential manner, not parallel. We positioned patients randomly in a queue and constrained the model to schedule patients in queuing order. This simple approach enhanced the model's non-anticipative feature. Finally, we developed robust MSSs to maximise throughput while keeping cancellations within limits. The simulation results indicated that the schedules obtained were promising.

#### 5 - Truck Driver Friendly Scheduling Problem a Constraint Programming Approach

Fereydoun Adbesh, J.B. Hunt Transport Inc, 615 J. B. Hunt Corporate Dr, Lowell, AR, 72745, United States, Brain Moore, Douglas Mettenburg

As a transportation company, development of quality work schedules is critical to the retention of drivers. Feasible driver schedules must strictly adhere to delivery appointments and Department of Transportation rules, while also considering soft constraints, such as schedules that start at roughly the same time each day. Several commercial software packages address the former but neglect important human factors. A constraint programming approach is developed to minimize the number of total drivers while increasing the driver-friendliness of the solution. The performance of the model is compared with results from a commercially available routing software over a set of real-world problems.

#### 6 - Developing Dispatching Rules for a Flexible Flow Shop Scheduling Environment at a Wind Mill Tower Assembly Facility

Leonardo Bedoya-Valencia, Colorado State University-Pueblo, 4702 Desert Candle Drive, Pueblo, CO, 81001, United States, Micah Mitchell

This research work proposes the developing of a simulation model used to evaluate different dispatching rules in a multi-stage flexible flow shop scheduling

environment (FFSSE). The process analyzed in this research is the rolling, welding and assembling of steel sheets required to manufacture the four sections of a wind mill tower. In this process, the utilization of the welding workstations is the most important measure of performance while keeping the throughput above a lower limit defined by the management of the company. Computational experiments were performed in order to define the group of best dispatching rules that maximizes the resources utilization.

## ■ WC52

North Bldg 231C

### Practice- Transportation Freight 1

Contributed Session

Chair: Juvvala Rambabur, Indian Institute of Technology Kharagpur, Kharagpur, India

#### 1 - Intermodal Freight Network Design Problem: Consideration of the Product Perishability

Maxim A. Dulebenets, Florida A&M University-Florida State University, Tallahassee, FL, 32311, United States, Eren Erman Ozguven, Ren Moses, Thobias Sando, Mehmet Ulak

A significant amount of products, transported via the existing freight transportation networks, are perishable in their nature. This study presents an optimization model for design of freight transportation networks with perishable products, aiming to minimize the total transportation cost, including the cost associated with decay of perishable products. A set of piecewise functions are adopted to linearize the original model. The linearized model is solved using CPLEX. Numerical experiments are performed for the seafood perishable products to draw a number of important managerial insights.

#### 2 - Recovery Optimization for Truckload Freight: Evidence from Practice

Roger D. Lederman, Amazon, Seattle, WA, United States

Our network of truckload freight carriers is critical to the promise of fast and reliable delivery. To achieve high standards of customer service, the network must respond efficiently to both internal and external disruptions. The talk will discuss our work in recovery optimization, which optimally allocates available trucks to maintain service, while minimizing the cost of disruption. Our solution is forward-looking, including proactive mechanisms to keep supply and demand in balance. The tools have improved network performance in the form of lower cancellation rates and decreased reliance on costly spot market capacity.

#### 3 - Investigating the Waiting Time & Carbon Emission Reduction Potential of the Urban Consolidation Centre

Juvvala Rambabu, Research Scholar, Indian Institute of Technology Kharagpur, ND 105 VSRC IIT Kharagpur, 721302, India, S. P. Sarmah

The purpose of this study is to examine the feasibility of the Urban Consolidation Centre (UCC) as a measure to minimize the negative impacts of freight transportation in the city such as congestion and carbon emission. We have employed the established meta-heuristic technique to the NP-hard nature of the mathematical model formulation

## ■ WC53

North Bldg 232A

### Behavioral Operations I

Contributed Session

Chair: Samuel Nathan Kirshner, UNSW Business School, Level 2, West Wing, Quadrangle Building, Sydney, 2052, Australia

#### 1 - Social Stress and the Newsvendor Problem

George Kurian, The University of Texas at Arlington, Arlington, TX, 76013, United States

This paper investigates the effect of social stress on individual performances in the newsvendor problem. From our experiments and analyses, we did not find sufficient evidence for the impact of social stress on performance. However, subjects showed less demand chasing and better learning under social stress. The results show that not all types of stress are detrimental.

#### 2 - An Experimental Study: Does the Influence of Leaderboard and Dynamic Ranking on Performance Depend Upon Task Type?

Sina Zare, University of Texas-Arlington, Arlington, TX, 76013, United States, Kay-Yut Chen, Sridhar P. Nerur

We investigated the effect of Leaderboard and dynamic ranking on the decision makers' performance in two different contest games. The first experiment is a Newsvendor task which requires subjects' cognitive skills to perform well in the experiment. In the second experiment, subjects are engaged in a real effort task where we study how their level of effort and efficiency change upon cost setting.



### 3 - The Impact of Service Level on Inventory Decisions

Jaime Andres Castañeda, Universidad del Rosario, Bogota, Colombia, Sebastian Villa

This study analyzes how a service level concern impacts inventory decisions. We experimentally manipulate decision makers' mindset through priming techniques to (unconsciously) activate a service level mindset aligned with profit maximization. We also explicitly model a service level target in the Newsvendor problem, providing the analytical solution, model insights and suggestions for a behavioral test of this (consciously) activated service level mindset.

### 4 - Impact of Behavioral Factors on Performance of Multi-server Queuing Systems

Marilyn T. Lucas, University of Vermont, School of Business Management, 202 Kalkin Hall 55 Colchester Avenue, Burlington, VT, 05405-0157, United States, Hung Do, Masha Shunko, David Novak

Recent studies have shown that employees in service-based queuing systems respond to the design and congestion level of the queuing system in which they operate. In this paper, we incorporate two behavioral effects into multi-server analytical queuing models: server speedup due to increased workload and server slowdown due to social loafing when multiple workers share the workload. We evaluate how these factors affect the performance of both the multi-server, single-queue (or SQ) system and the multi-server, parallel-queue (or PQ) system. We also consider strategic routing and its impact on the performance of PQ systems.

### 5 - Construal Level Theory and the Newsvendor Problem

Samuel Nathan Kirshner, UNSW Business School, Level 2, West Wing, Quadrangle Building, UNSW, Sydney, 2052, Australia, Chun-Tang Pai

Experimental studies on the newsvendor problem has robustly observed that subjects choose order quantities that systematically deviate from the profit maximizing order quantity. Construal Level Theory (CLT) shows that people can be subconsciously primed by their environment to think more abstractly (high construal) or concretely (low construal), which in turn, can predictably influence decision-making. This talk investigates the potential impacts of CLT on demand chasing in the newsvendor problem.

## WC54

North Bldg 232B

### Behavioral Operations Management Session

Sponsored: Behavioral Operations Management

Sponsored Session

Chair: Xiaobo Zhao, Tsinghua University, Beijing, 100084, China

Co-Chair: Wanshan Zhu, Tsinghua University, Beijing, 100084, China

#### 1 - What Can We Learn from Brain Imaging Newsvendors?

Kay-Yut Chen, University of Texas at Arlington, 511 Pine Island Circle, Mansfield, TX, 76063, United States

The current literature on newsvendor behavior relies on "guessing the underlying cognitive mechanisms from observations, without direct physical evidence. Functional near infrared spectroscopy allows researchers to examine brain functions by measuring hemodynamic responses. In this paper, we show that newsvendor performances are correlated with neural activations, which can be interpreted as cognitive efforts.

#### 2 - Full Credit or Full Quantity? A Behavioral Investigation of Buyback Contracts

Yinghao Zhang, Assistant Professor, University of Cincinnati, 614A Carl H. Lindner Hall, 2925 Campus Green Dr., Cincinnati, OH, 45221, United States, Peiwen Yu, Tianjun Feng, Stephanie N. Eckerd

This paper investigates two forms of buyback contracts: full quantity and full credit contracts. Standard theory suggests that the retailer should order the same amount of inventory under these two options. Lab experiments, however, reveal different ordering patterns. We propose a behavioral model to explain these experimental observations.

#### 3 - How to Provide Information for Management Decisions

Jaime Andres Castañeda, Universidad del Rosario, Bogotá, Colombia, Yingshuai Zhao

This work experimentally studies several ways of providing information in a newsvendor task to pinpoint decision-making improvement interventions. Based on sunk-cost effects arguments, we manipulate (i) whether decision makers obtain supporting information for free or at a cost, and based on instrumental information arguments, we manipulate (ii) the feedback information provided. Results show (i) performance improvements when participants have to pay for supporting information and (ii) less order variability when they are provided with instrumental information.

### 4 - On Difference between Direct-response and Strategy Procedures in Decision Making: Neural Evidence in a Reward-punishment Game

Niannian Sun, Tsinghua University, Beijing, China, Xiaobo Zhao, Lihong Wang, Yukun Zhao, Xue Xiao

In decision making, the evidence of whether direct-response procedure and strategy procedure lead to similar outcome is mixed. We conduct an fMRI experiment of a game setting with reward and punishment decisions under both procedures. The results show that, in reward decision, the direct-response procedure prompts stronger neural unwillingness and lower reward rate than the strategy procedure. In punishment decision, the strategy procedure induces stronger neural negative emotions and higher punishment rate than the direct-response procedure. Moreover, subjects prefer not to choose reward when facing favorable states but tend to choose punishment when facing unfavorable states.

## WC55

North Bldg 232C

### Product and Project Development and Management 1

Contributed Session

Chair: Barbaros Yet, Hacettepe University, Ankara, Turkey

#### 1 - Factors Affecting Labor Productivity in Turnaround Maintenance Projects: Case of the Oil and Gas Sector in Qatar

Omar Ben-Ayed, Professor of Management, Qatar University, College of Business and Economics, Department of Management and Marketing, Doha, Qatar, Abdulhadi Nasser Al-Marri, Salem Nechi

The aim of this study is to define the factors affecting labor productivity in Turnaround Maintenance (TAM) projects in the oil and gas sector in Qatar and to propose solutions to improve it. We use the Analytic Hierarchy Process method to determine the importance of the factors identified and to select the most appropriate managerial alternative for improvement. The target participants are mostly from the management level of TAM companies. The results show that the top five factors are labor skills, extent of supervision, communication skills, safety related issues, and on-site labor transportation. The study suggests improving the estimation of activity time and resources.

#### 2 - Coordination between Iterations and Design Rate in Serial Product Development Process

Maoqi Liu, PhD Candidate, Tsinghua University, Beijing, 100084, China, Li Zheng, Changchun Liu

Product Development (PD) plays an important role in winning market competition. As complexity and uncertainty increasing in PD process, iteration becomes more and more significant in this process. Lead time is a key indicator to measure the performance of PD process. Many techniques like CPM and PERT are applied to non-iterative process but few of them can be applied in iterative one. In this research, a model is proposed to achieve best coordination between faster and fewer iteration with the object of minimizing lead time of PD process. The results in small scale shows that task with higher risk tends to design slowly to reduce iterations and therefore, shorten PD lead time.

#### 3 - Probabilistic Earned Value Management using Bayesian Networks

Barbaros Yet, Dr., Hacettepe University, Ankara, Turkey, Yasemin S

Accurate project control is challenging due to uncertainty regarding the completion percentage of ongoing activities and uncertainty of the project plan. Our aim is to develop a probabilistic project control tool based on Earned Value Management (EVM). We use Hybrid Bayesian Networks (HBN) to model the causal relations between project risk factors and progress, and to reflect parameter uncertainty in EVM. The proposed tool is illustrated using a case study of a construction project.

## ■ WC57

West Bldg 101B

### Mathematical Modeling and Optimization for Cancer Therapy

Sponsored: Health Applications

Sponsored Session

Chair: Ehsan Salari, Wichita State University, Wichita, KS, 67260, United States

#### 1 - Dose Mimicking with Inverse Optimization

Aaron Babier, University of Toronto, Toronto, ON, M5S 2K6, Canada, Andrea McNiven, Timothy Chan

There are many instances in radiotherapy (e.g., knowledge-based planning) where we know what a desirable dose distribution looks like, but we do not know how to deliver it to a patient. In these cases, dose mimicking methods are used to optimize the beamlets that best deliver the plan in question. We propose an inverse optimization (IO) pipeline as an improvement over conventional dose mimicking methods. After testing both approaches on clinical plans and predictions from a random forest, we found that our IO approach can mimic plans better than a conventional method. These results were consistent across a large cohort of 217 patients, and suggest that IO is a viable tool for dose mimicking.

#### 2 - Effects of Spatial Structure on the Speed of Evolution

Nathaniel Witte, University of Minnesota, Minneapolis, MN, United States, Kevin Leder

Spatially structured and spatially homogeneous models are both commonly used to model cancer growth. In this work, we consider two stochastic models of tumor evolution: a logistic branching process and an interacting particle systems. In particular, we are interested in how the average population fitness changes versus time in the two models. We also investigate how spatial structure affects tumor response to therapy.

#### 3 - Optimizing Spatiotemporally Fractionated Radiotherapy Plans

Ali Adibi, Wichita State University, Wichita, KS, 67220, United States, Ehsan Salari

Several studies have recently shown the potential therapeutic gain that may be achieved from delivering spatiotemporally fractionated radiotherapy plans. However, solving the corresponding treatment planning problem to a small optimality gap remains computationally challenging for 3D clinical cases due to the large-scale and non-convex nature of the problem. This research aims at developing a customized solution approach to spatiotemporal fractionation.

#### 4 - Organ Motion Prediction in MRI Guided Radiotherapy

Seyed Ali Mirzapour, Wichita State University, Wichita, KS, 67220-2982, United States, Thomas Mazur, Gregory Sharp, Ehsan Salari

Internal organ motion during radiation therapy (RT) is a major concern in the treatment of lung and abdominal cancers. If unaccounted for, the anatomical motion may lead to the underdosing of the target volume or overdosing of organs at risk. A new generation of RT systems are equipped with onboard magnetic-resonance imaging (MRI) scanners, providing a real-time view of the anatomical motion during RT delivery. This research aims at employing the online stream of MRI images to predict the motion trajectory using Markov processes.

## ■ WC58

West Bldg 101C

### Resource Allocation in Health Care

Sponsored: Health Applications

Sponsored Session

Chair: Jackie Griffin, Northeastern University, Boston, MA, 02115, United States

#### 1 - Approximate Dynamic Programming for the Aeromedical Evacuation Dispatching Problem: Value Function Approximation Using Multiple Level Aggregation

Nathaniel D. Bastian, Assistant Professor, Department of Systems Engineering, U.S. Military Academy, West Point, NY, 10996, United States, Matthew Robbins, Phillip Jenkins, Brian Lunday

Sequential resource allocation decision-making for the military medical evacuation of wartime casualties consists of identifying which available aeromedical evacuation (MEDEVAC) assets to dispatch in response to each casualty event. These sequential decisions are complicated due to uncertainty in casualty demand and service times. In this research, we present a Markov decision process model solved using a hierarchical aggregation value function approximation scheme within an approximate policy iteration algorithmic framework. The model seeks to optimize this sequential resource allocation decision under uncertainty of how to best dispatch MEDEVAC assets to calls for service.

#### 2 - Resource Allocation for Medical Fraud Assessment

Tahir Ekin, Texas State University, San Marcos, TX, 78666, United States, Rasim Musal

It is estimated that up to 10 percent of annual health care spending is lost to fraudulent transactions, which makes medical audits paramount. The resource allocation decisions for the medical audits are challenging because of the heterogeneity of the claims. A number of frameworks are utilized to help auditors address the trade-offs between efficiency and cost while having valid overpayment amount estimates. We present resource allocation designs to help the auditors assess the trade-off between the initial and additional numbers of samples within a multistage sampling framework.

#### 3 - Productivity-driven Physician Scheduling in Emergency Departments

Nadia Lahrichi, Ecole Polytechnique de Montreal, Cp6079 Succ. Centre-Ville, Montreal, QC, H3C3A7, Canada, Dina Bentayeb, Louis-Martin Rousseau

Reducing the congestion in EDs is a major challenge for improving access to care. Our approach to deal with this problem is to offer an innovative approach to scheduling emergency physicians. Currently, departments define a covering constraint that fixes the number of required physicians per shift/day. We observe two main issues: 1) the variation in demand in terms of number of patients is not considered when designing the schedule; 2) all physicians are considered equivalent in terms of the number of patients they see in a shift. These two aspects lead to a mismatch between offer and demand. In this project, we will address these two issues to better align the schedule of physicians to patients demand.

#### 4 - Patient Prioritization in an Ambulatory Care Clinic Using Markov Chain Models

Vahab Vahdatzad, Northeastern University, Boston, MA, 02114, United States, Jacqueline Griffin, Ann Suhaimi

In outpatient centers, physicians regularly visit patients with different characteristics. Furthermore, physicians may visit each patient multiple times during one visit. An example of multiple visit is in orthopedic centers that physician visit the patient before and after radiology tests. In this research, prioritizing patients are examined using Queueing Network and Markov chain models and showed how altering prioritization based on patient characteristics can improve timeliness of care for all patients.

## ■ WC59

West Bldg 102A

### Operational Decisions in Healthcare

Sponsored: Health Applications

Sponsored Session

Chair: Zhankun Sun, City University of Hong Kong, Kowloon, 1, Hong Kong

#### 1 - Design of Specialist Response Policies to Reduce Waiting Time in Emergency Departments

Cheng Zhu, McGill University, 701-801 Sherbrooke Est, Montreal, QC, H2L 0B7, Canada, Beste Kucukyazici

We design a framework of systematic response policies for specialists based on their clinical demands. After identifying a class of patients who are more likely to require specialist consultation based on their clinical information available at the triage stage through statistical analysis, we analyze several alternative policies for specialists' responses to consultation requests using queueing models. Specifically, we analytically calibrate a specialist's optimal arrival in a cycle based on the non-homogenous Poisson distributed demand. The simulation suggests this policy can be effectively adopted in different types of hospitals with varied patient volumes.

#### 2 - Bed Allocation to Reduce Overflow

Jingui Xie, University of Science and Technology of China, School of Management, 96 Jinzhai Road, Hefei, 230026, China, Marcus Teck Meng Ang, Mabel Chou, David D. Yao

To address the overflow issue, we build an analytical model and propose two easy-to-compute bed allocation policies. We use the real data from the only university hospital in Singapore and a simulation model to evaluate the effectiveness of our proposed policies against the base case provided by the empirical study of the hospital. Through the simulation study, we show that the proposed policies can reduce the overflow rate from 18.91% to about 4-5% without sacrificing other performance measures. More surprisingly, our simulation studies suggest that the existing capacity actually can accommodate 50% more elective patients while keeping the overflow rate at a level of less than 10%.

### 3 - Dialysis Facilities: Does Location, Staffing, and Mode Impact Access to Care?

Michael G. Klein, San Jose State University, One Washington Square, San Jose, CA, 95192-0069, United States

Kidney failure is treated with dialysis until transplant or death. Regardless of the travel burden, many patients always opt to go to a facility, while some always opt for home dialysis. For others, the choice varies depending on the location of available facilities. Existing patients also switch dialysis modes (e.g. from facility-based dialysis to home dialysis) bringing different requirements for providers over time. I propose a new model to determine the best network of dialysis facilities from an access to care perspective. Through a California case study, I propose to illustrate the model and help identify areas for improvement.

### 4 - Readmission Reduction Programme for COPD Exacerbation: From Predictive to Prescriptive Analytics

Shaochong Lin, City University of Hong Kong, 5022, AC2, Kowloon Tong, Hong Kong, Frank Y. Chen

Chronic Obstructive Pulmonary Disease (COPD) is a chronic, non-reversible lung disease. Based on a predictive model, we can early identify high-risk subpopulation with high accuracy for further follow-up interventions. This work aims to use the predictive model to guide allocation of limited health care resources to balance efficiency - readmission reduction and health outcomes.

## ■ WC61

West Bldg 102C

### Supply Chain Optimization II

Contributed Session

Chair: Anurag Agarwal, University of South Florida, Information Systems and Decision Sciences, Coll of Business, Sarasota, FL, 34243, United States

#### 1 - Optimal Decision of Supply Chain with Consumer Returns in Electronic Commerce

Wenjuan Wang, Dongbei University of Finance and Economics, Dalian, China

The impacts of the customer's behaviors can damage the profits of supply chain with customer returns. Some related knowledge of consumer return in supply chain is summarized. We estimate customer demand through a choice model, which incorporates reference price, utility function and customer loss aversion. We analyze the optimal and equilibrium strategies for a seller operating. Our system can improve the efficiency of decision making and provide better customer service for the enterprise's operation.

#### 2 - Matching and Revenue-risk Sharing Contract with Heterogeneous Risk Averse Supplier and Retailer

Hewen Liu, University of Miami, Miami, FL, United States

The following analysis covers a decentralized matching model with a bilateral supply chain including risk averse suppliers and retailers. I characterize the stable matchings with endogenous production plan and revenue sharing contract. Depending on the trade-off between the expected revenue and demand uncertainty, both positive assortative matching (PAM) and negative assortative matching (NAM) can occur at a stable matching equilibrium. These results shed light on the role of the endogenous production plan in coordination supply chain allocation and inventory management.

#### 3 - Evaluating the Tradeoff between the Delivery Cost and Customer Lead Time in Last Mile Delivery

Sanam Azadiamin, PhD Candidate, Ohio University, Athens, OH, 45701, United States, Dale Masel

In supply chain, the purpose of last mile delivery is to deliver items to customers in manageable cost and time. For this purpose, vehicle routing problem has been used to solve the problem considering both delivery cost and customer lead time factors by examining the impact of driver's batch size on both factors. The travel area's largeness has also been considered in finding the optimal solution.

#### 4 - Heuristics versus Exact Method Comparison of a Supply Chain Scheduling Problem with Penalties

Anurag Agarwal, University of South Florida, Information Systems and Decision Sciences, Coll of Business, Sarasota, FL, 34243, United States, Ramakrishna Govindu

Given the complexity of supply chain scheduling problems, they are solved by applying heuristics (using due times and other improvisations) and metaheuristics to find good solutions quickly. Better formulations can help reduce the time for exact solutions. We investigate the performance comparisons between multiple heuristics and an exact method on a supply chain scheduling problem.

## ■ WC62

West Bldg 103A

### Joint Session DM/Practice Curated: Data Science in Health Care III

Sponsored: Data Mining

Sponsored Session

Chair: Maryam Soltanpour Gharibdousti, Binghamton University, 1120 Murray Hill Road, Vestal, NY, 13850, United States

#### 1 - Studying Impact of Physical Activity on Human Learning Propensity and Emotional Response Modulation using EEG Data

Klim Drobnyh, Arizona State University, Tempe, AZ, 85281, United States, Ghazal Shams, Robert Atkinson, George Runger

The goal of our study was to investigate the impact of acute and chronic physical activity on learning propensity and emotional response modulation. Two groups of participants with high and low levels of exercise were instrumented with EEGs and tested for cognitive load, and furthermore different stimuli were presented. This generated high-volume, rich datasets, and several analytical tasks were completed to handle this high-volume data.

#### 2 - Hospital Length of Stay Prediction Model for Neurosurgery Inpatients Applying Various Data Mining Techniques

Sahar Khamsehi, SUNY Binghamton, 4400 Vestal Pkwy E, Binghamton, NY, 13850, United States

Prolonged length of stay (LOS) at hospitals have been controversial topic that leads to extra cost for hospitals. Consequently, it increases patients' turnaround time. The purpose of this study is to determine non-clinical factors that may prolong length of stay and develop predictor models using contributing factors. The results from three prediction techniques of Artificial Neural Network (ANN), Logistic Regression (LR) and Support Vector Machine (SVM) obtained from neurosurgery database for a period of 2 consecutive years inclusive of 14 non-clinical factors, are statistically compared. Conclusively, logistic regression has the highest accuracy among all data mining techniques.

#### 3 - Survival Rate Prediction in Cardiac Patients with Heart Transplant or Assisted Devices

Maryam Soltanpour Gharibdousti, PhD Candidate, Binghamton University, 4400 Vestal Pkwy E, Binghamton, NY 13902, Vestal, NY, 13902, United States, Mohammad Khasawneh

The survival rate prediction for the organ transplant surgery patients can help to classify patients risk levels and potential post-surgical complications. The research used the data for cardiac patients with either medical assist devices such as Impella and Left Ventricular Assist Devices (LAVD) or heart transplant patients. The significant factors such as demographic information, baseline patient characteristics, baseline hemodynamics, laboratory values, and in-hospital complications can predict the survival rate after the transplant surgery. The data from one of the Organ Procurement Organizations (OPO) in New York State is analyzed using several machine learning algorithms.

## ■ WC63

West Bldg 103B

### Joint Session DM/Practice Curated: Data Science for Operations and Quality Management

Sponsored: Data Mining

Sponsored Session

Chair: Yanqing Kuang, University of South Florida, Tampa, FL, United States

#### 1 - Data-driven Consumer Debt Collection via Machine Learning and Approximate Dynamic Programming

Qingchen Wang, Amsterdam Business School, Amsterdam, Netherlands, Ruben van de Geer, Sandjai Bhulai

This paper presents a novel data-driven framework for the optimization of the consumer debt collection process. We consider the problem of scheduling outbound calls made by debt collectors to a portfolio of debtors with heterogeneous and dynamic repayment behavior. We model this problem as a Markov decision process and approximate the value function based on predictions of individual debtors' repayment probabilities by leveraging historical data and using a state-of-the-art machine learning technique. A controlled field experiment with an industry partner showed an increase in collected cases at a significant decrease in calling efforts compared to their current collection policy.



## 2 - Optimal Return Policy in the Presence of Social Networks

Ehsan Salimi, University of Florida, 376 Weil hall, Gainesville, FL, 32603, United States, Sina Ansari

When a firm allows the return of purchased item, it provides customers with the option of keeping or returning the item. While the option to return item leads to an increase in gross revenue, it may also create additional costs including the social costs associated with returns. In this paper, we study the optimal return policy considering customers' returns behavior in the presence of social networks. Our findings have important implications for the coordination of marketing and operations decisions.

## 3 - An Anatomy-adjusted Quality Control Tool for Cancer Radiotherapy Plan Evaluation

Arkajyoti Roy, The University of Texas at San Antonio, San Antonio, TX, United States  
Arkajyoti Roy, Bowling Green State University, Bowling Green, OH, United States, Dan Cutright, Mahesh Gopalakrishnan, Arthur Yeh, Bharat B. Mittal

A quality control tool is proposed that allows clinicians to evaluate and directly compare cancer radiation treatment quality of a large set of patients, after accounting for variations in patients' anatomies. The effect of the inter-patient variations is accounted for through the use of anatomy-adjusted I-Charts. 69 head-and-neck cancer cases are used for the evaluation of the proposed tool.

## 4 - Statistical Monitoring of Inhomogeneous Continuous Time Markov Chains

Yanqing Kuang, University of South Florida, Tampa, FL, United States, Devashish Das, Jianguo Wu, Mustafa Y. Sir

In this presentation, we propose a nonparametric scheme for monitoring inhomogeneous continuous time Markov chains with a large state space. The proposed framework is used to monitor the timeliness of the healthcare delivery process using time-stamped clinical event sequences.

## WC64

West Bldg 104A

## Joint Session DM/Practice Curated: Data Science for Transportation Related Applications

Sponsored: Data Mining

Sponsored Session

Chair: Sang Min Lee, Korea University, Seoul, Korea, Republic of

## 1 - Detecting Crash Severity in Passenger Vehicle a Machine Learning Study

Rupesh Agrawal, Research Assistant, Oklahoma State University, 700 N. Greenwood Ave, Tulsa, OK, 74106, United States, Robert Fritts, Dursun Delen

In 2016, National Highway Traffic Safety Administration reported nearly a trillion-dollar impact from the loss of productivity, loss of life, and other consequences related to automobile crashes. This study seeks to enhance the current body of knowledge in discovering variables impacting the level of injury severity in passenger vehicle accidents using variable selection and data balancing techniques (i.e., oversampling and undersampling) using multidimensional, feature-rich, and highly-structured data with Machine Learning algorithms.

## 2 - Conditional Monitoring of Wheel Wears for High-speed Trains: A Data-driven Approach

Peiwen Xu, PHD Candidate, City University of Hong Kong, 88 Tat Chee Avenue, AC1, Hong Kong, Hong Kong, Weiran Yao, Yang Zhao, CAI YI, Lishuai Li, Jianhui Lin, Kwok-Leung Tsui

The rapid expansion of high-speed railway network is placing increased emphasis on the optimization of the maintenance process to enhance the availability and efficiency of the train system with a high standard of safety and reliability. A data-driven method is proposed to monitor wheel wears in a high-speed railway system. The result can provide an early warning of a component degradation, enabling the switch from fixed interval maintenance to condition-based maintenance. The proposed method combines signal processing and statistical methods to extract relevant information from vibration data and then predict wheel wears. The accuracy of this method is tested by real operational data in China.

## 3 - Incremental Learning for Nonstationary Traffic Control in Automated Vehicle Systems

Sang Min Lee, Korea University, 221 New Engineering Building, Korea Univ., 145 Anam-ro, Seongbuk-gu, Seoul, Korea, Republic of, Sung Ho Park, Seoung Bum Kim

We introduce an incremental learning method for adaptive traffic control in a large-scale automated vehicle system. We present a change-aware learning method that combines a change detector with adaptation algorithms. To demonstrate the effectiveness of the proposed method, we conducted an experimental study to evaluate the predictive performance using the high-fidelity simulator.

## WC66

West Bldg 105A

## Reliability I

Contributed Session

Chair: Yuan Chen, Ohio University, Athens, OH, 45701, United States

## 1 - Assessing a Maintenance Outsourcing Production System under Presence of Cyber Threats and Channel Coordination

Anh Ta, University of North Texas, Denton, TX, 76205, United States, Hakan Tarakci, Shailesh S. Kulkarni, Victor R. Prybutok

Outsourcing of maintenance is desirable in many production systems. The Internet of Things (IoT) enabled "smart manufacturing systems but the resulting connected format makes these systems potential targets for cyber-attacks. This study assesses maintenance outsourcing for potential cyber threats as well as channel coordination cost subsidization. We provide guidelines and quantify the effect of various monetary, reliability and cyber-attack parameters.

## 2 - Production Control to Reduce Waste Productions in a Two-machine-one-buffer Bernoulli Serial Line

Penghao Cui, Northwestern Polytechnical University, NO.127, West Youyi Road, Xi'an, Xi'an, 710072, China, Junqiang Wang

We study production control problems in a two-machine-one-buffer Bernoulli serial line including waste production. In such a system, the second machine produces a certain number of non-standard quality productions each time it restarts after a stop either a failure or a starvation. Using a Markov model, an optimal control policy is developed to restore the buffer to a predefined threshold each time it gets empty for reducing starvation frequency of the second machine. Closed-form expressions of performance measures are derived and the effect of the policy is carried out by comparing with a serial line without it.

## 3 - Reliability-redundancy Optimization for Continuous-state Series-parallel System with Degrading Components

Yuan Chen, Ohio University, Athens, OH, 45701, United States, Tao Yuan

This presentation discusses a reliability-redundancy optimization problem for continuous-state series-parallel systems consisting of degrading components. A structure function is introduced to describe the relationship between the state of the system and the states of the components over time. An optimization model that maximizes the reliability of the system subject to a cost constraint is proposed to find the optimal redundancy design. A battery pack system for electric vehicle applications is employed to illustrate the proposed methodology.

## WC67

West Bldg 105B

## Joint Session ISS/SMA: Social Media and Information Systems

Sponsored: Information Systems

Sponsored Session

Chair: Xue Tan, Indiana University, Bloomington, IN, 47405, United States

## 1 - Can Your Facebook Page Likes Predict Your Dating Behavior?

Behnaz Ghahestani Bojd, University of Washington, Seattle, WA, 98105, United States, Yong Tan

Many existing dating apps require users to login with their social media accounts. For example, apps like Tinder require a Facebook login to use its service. This grants the apps access to select Facebook data, which speeds up the process of creating dating profiles. It also helps companies detect fake profiles. In this study, using data from an online dating app, we study the relationship between users' Facebook page likes and their dating preferences, and app usage. Although users do not observe each other's Facebook page likes, their interests affect their dating judgments.

## 2 - Linking Clicks to Bricks: Spillover Benefits of Online Advertising

Mi Zhou, Carnegie Mellon University, Pittsburgh, PA, 15217, United States, Vibhanshu Abhishek, Edward Kennedy, Kannan Srinivasan, Ritwik Sinha

Businesses have widely used email ads to send promotional information to consumers. While email ads serve as a convenient channel to target consumers online, are they effective in increasing offline revenues for firms that predominantly sell in physical stores? Is the effect heterogeneous across different consumer segments? If so, on which consumers is the effect highest? We address these questions using a big dataset from a large domestic retailer. Using a doubly robust estimator that incorporates machine learning methods for causal estimation, we find email ads can increase a consumer's spending in physical stores by \$11.8, and the effect is highest among those with fewer interactions recently.

### 3 - Driver Retention in Ride-sharing Services: An Empirical Study

Kyungsun (Melissa) Rhee, University of Washington, Seattle, WA, 98105, United States, Jinyang Zheng, Yong Tan, Fei Ren

With the growing popularity of global sharing economy market, on-demand ride-sharing services have become an important transportation channel. However, there is a rising concern on retaining drivers in ride-sharing platforms; they do not necessarily earn a significant amount of profit due to an increasing competition between the drivers and frequent order cancellations. By leveraging data from Chinese leading on-demand ride-sharing platform, we examine how spatial and temporal characteristics of passengers' trips affect drivers' behaviors of using ride-sharing apps. We extend the investigation to find out how drivers such behaviors affect their decision on staying/leaving the platform.

## ■ WC68

West Bldg 105C

### Joint Session QSR/Practice Curated: Data Analytics for Advanced Manufacturing Systems

Sponsored: Quality, Statistics and Reliability

Sponsored Session

Chair: Wenmeng Tian, Mississippi State University, MS, 39762, United States

Co-Chair: Hongyue Sun, University at Buffalo, Buffalo, NY, 14260, United States

#### 1 - Spatial-temporal Modeling for the Additive Manufacturing Process of Ti-6Al-4V

Weihong Guo, Rutgers, The State University of New Jersey, 96 Frelinghuysen Rd, CoRE Rm 220, Piscataway, NJ, 08854, United States, Shenghan Guo, Linkan Bian

This study focuses on modeling the data indicating temperature and heat transfer within the melt pool and heat affected zone atop a thin-walled structure of Ti-6Al-4V during its additive manufacture. A spatial-temporal model is developed to quantify the temperature, heat transfer, and laser-induced, powder-fed melt pool characteristics. The proposed method is integrated with Bayesian inferences for online adaptive modeling and monitoring. A novel control chart is developed to monitor the model parameters to support decision making. The performances of several spatial-temporal models are compared using experimental data.

#### 2 - Customized Modeling for Multi-stage Additive Manufacturing Systems

Hongyue Sun, University at Buffalo, 319 Bell Hall, Industrial and Systems Engineering, Buffalo, NY, 14260, United States, Ramanarayanan Purnanandam, Chi Zhou

Most existing works on additive manufacturing (AM) focus on the single-stage printing at a local 3D printer, and fail to analytically quantify the effect of material preparation and post-processing stages on the printed part quality. To fully investigate AM, multiple stages (both AM and its up-stream and down-stream processes) need to work synergistically. However, the complex functional variable relationships among multiple stages pose challenges for conventional data analytics models. In this work, we propose customized models to address the problem. Both simulation and a constrained-surface stereolithography (SLA) process are used to demonstrate the proposed method.

#### 3 - Online Monitoring for Additive Manufacturing Processes Based on Image Sequence Analysis

Wenmeng Tian, Mississippi State University, P.O. Box 9542, Mississippi State, MS, 39762, United States, Mehrnaz Esfahani, Linkan Bian

The melt pools in thermal images are regarded as the most informative process signature in metal-based additive manufacturing (AM) processes, and thus can be used for real-time process monitoring. However, how to effectively extract features from a series of melt pools for anomaly detection in each fabricated layer is still an open question. In this work, we propose a novel feature extraction approach by formulating the melt pool contours of one entire layer as a 3D space-time object. Low dimensional features can be extracted to characterize the shape variability in the 3D object. A case study based on a thin wall fabrication process is used to validate the proposed approach.

## ■ WC69

West Bldg 106A

### Statistical Methods for Modern Reliability Data Analysis

Sponsored: Quality, Statistics and Reliability

Sponsored Session

Chair: Wujun Si, Wayne State University, Detroit, MI, United States

Co-Chair: Qingyu Yang, Wayne State University, Detroit, MI, 48202, United States

#### 1 - A General Repair Model with Dynamic Covariate Information and Application in Optimal Maintenance Planning

Wujun Si, Wichita State University, Wichita, KS, 67206, United States, Qingyu Yang

We propose a novel general repair model when dynamic covariate information is presented. Based on the repair model, we develop an optimal maintenance planning strategy subject to dynamic covariates. A maximum likelihood estimation method is developed to estimate the model parameters. A simulation study is implemented to illustrate the developed methods, and a real world case study is conducted to demonstrate the proposed model.

#### 2 - Event Prediction for Individual Unit Based on Time-to-event Data Collected in Teleservice Systems

Akash Deep, University of Wisconsin Madison, Madison, WI, United States, Dharmaraj Veeramani, Shiyu Zhou

We present a semi-parametric method to predict the event occurrence for an individual unit in real-time using time-to-event data. The units we consider are prone to experience the event multiple times during their usage lifetime, and these events are critical to overall performance of the system. The hazard of event-occurrence is modeled using Cox PH model and the distinction of units is achieved using a frailty parameter. The method features an on-line updating scheme, therefore, it can provide real-time prediction of the occurrence of next event. We demonstrate the efficacy of frailty and the updating scheme through comprehensive numerical experiments and a case study based on real-world data.

#### 3 - Analysis of Large Repairable System Reliability Data with Static System Attributes and Dynamic Sensor Measurement

Xiao Liu, University of Arkansas

Leveraging modern statistical learning and conventional repairable system reliability analysis methods, this work investigates a statistical analysis approach which integrates the Random Forests algorithm and the classical statistical reliability data analysis methods.

#### 4 - Optimal Maintenance Policies for Multi-level Preventive Maintenance with Complex Effects

Yisha Xiang, Lamar University, Yue Shi

Existing maintenance literature mainly focus on a single type of preventive maintenance action and often make simple assumptions regarding the effects of maintenance activities. Many important maintenance effects are overlooked in these models, e.g., deterioration rate reduction and random duration of a maintenance effective period. In this research, we consider joint planning for multiple levels of preventive maintenance with complex effects, and formulate the problem as a Markov decision process. Structural properties of the optimal policies are investigated by minimizing the total expected discounted costs. Numerical examples are conducted to validate our proposed model.

## ■ WC70

West Bldg 106B

### Practice- Quality & Reliability Engineering I

Contributed Session

Chair: Mejdal Alqahtni, Rutgers Univ., Bound Brook, NJ, 08805, United States

#### 1 - Power Systems Reliability Assessment with Variance Reduction and Markov Chain Monte Carlo

Daniela B. Almeida, PSR, Centro Empresarial Rio, Praia de Botafogo 228 / 1701-A Rio de Janeiro, RJ, Rio de Janeiro, 22250-145, Brazil, Carmen L. Borges, Gerson C. Oliveira

The methodology combining Variance Reduction and Markov Chain Monte Carlo significantly reduces the computation time and number of samples required for reliability studies compared to the standard Monte Carlo simulation. Some results from a study with real power systems are presented to highlight the effectiveness of the proposed method.

## 2 - Condition-based Maintenance (CBM) Optimization for a Two-component System through State Discretization and Proportional Hazard Model (PHM)

Mengkai Xu, Northeastern University, Boston, MA, 02115,  
United States, Noor E. Alam, Sagar S. Kamarthi, Xiaoning Jin

CBM of mechanical systems with stochastic dependence among their components has drawn much attention recently. Researchers commonly assume the independence of degradation and failure of multiple components to keep the models simple. However, the existence of degradation and failure interactions diminishes the accuracy of the models. To address this issue, the state-rate dependence denoting interaction between degradation states and hazard rates is proposed. A state discretization technique integrated with PHM aimed at capturing the effect of state-rate dependence for maintenance optimization is presented.

## 3 - Stochastic Modeling of Corrosion Growth

Changxi Wang, Ph.D Student, Rutgers University, Piscataway, NJ, 08854, United States

Corrosion growth modeling is important in industry. Existing methods model corrosion pits depth growth and estimate reliability accordingly. However, volume loss may also lead to failures such as rupture even if corrosion pits depth is small, which usually cannot be captured by such models. We develop a degradation model that captures corrosion volume growth, as well as corrosion depth growth. The influence of stresses on corrosion growth is considered. The distribution of volume loss increments and failure probability in the next time increment is obtained.

## 4 - Study on Travel Reliability of Urban Rail Transit Network Using Automatic Fare Collection Data

Yong Yin, Southwest Jiaotong University, Chengdu, China  
Yong Yin, National United Engineering Laboratory of Integrated and Intelligent Transportation, Chengdu, China, Jie Liu,  
Qiyuan Peng, Xu Yan, Anjun Li

It is important to study the travel reliability of Urban Rail Transit network to ensure people travel through Urban Rail Transit. The OD matrix and travel time between stations are obtained through Automatic Fare Collection data. Three reliability indicators that considering tolerable index are constructed from the aspects of network connectivity, travel time and transport capability. Taking Chengdu Urban Rail Transit as an example, five workday data of Urban Rail Transit are analyzed. The results show that the multi-state model is more effective than single model to fit the travel time distribution and tolerable index has a huge influence of the travel reliability of Urban Rail Transit network.

## 5 - Process Monitoring Of Three-dimensional Topographic Surfaces

Mejdal A. Alqahtni, Rutgers University, New Brunswick, NJ, 08901-8554, United States, Elsayed A. Elsayed, Myong K. Jeong

This paper develops a real-time monitoring approach for assessing the quality of 3D topographic surfaces. The approach initially improves the representation of 3D surface features by slicing the 3D surface topography into several layers. The functional spatial randomness (FSR) profile is then suggested for surface characterization in which the spatial randomness of topographic values is computed at each layer. By utilizing the functional principal component analysis (FPCA), an anomaly detection approach based on FSR profile is proposed. The developed approach reveals outstanding performance compared to the existing approaches in identifying various forms of surface defects.

## ■ WC71

West Bldg 106C

## Decision Diagrams and Optimization

Sponsored: Computing

Sponsored Session

Chair: Willem van Hoeve, Carnegie Mellon University, Pittsburgh, PA, 15213, United States

## 1 - An MDD-based Formulation for Scheduling Clinical Rotations

Tallys Yunes, University of Miami, Coral Gables, FL, United States,  
Andre Augusto Cire, Adam Diamant

We study the scheduling problem of a medical school that must assign a cohort of students to a set of clinical rotations, subject to operational and QoS constraints. Students become eligible for clerkship throughout the year and complete rotations at hospitals in different regions. Each hospital offers a subset of the rotations, with different start dates, capacities, and cost rates. We propose a network-flow formulation based on MDDs that is computationally superior to an MILP model and provides useful managerial insights. Using a real-life dataset, we run a discrete-event simulation of the assignment process. Compared to current practice, we achieve an average cost reduction of 25%.

## 2 - Integer Programming Postoptimality Analysis Using Decision Diagrams

John Hooker, Carnegie Mellon University, Tepper School of Business, Pittsburgh, PA, 15213, United States, Thiago Serra

We show how a decision diagram can compactly represent all solutions of an integer programming problem that are within a given tolerance of the optimal value. The structure of the diagram facilitates rapid processing of a wide range of queries about the near-optimal solution space. "Sound decision diagrams can more compactly represent near-optimal solutions by innocuously admitting some spurious solutions. In fact, repeated application of a simple "sound reduction operation yields a smallest possible sound diagram for a given problem instance. Computational tests show that it is typically far smaller than a tree representing the same set of solutions.

## 3 - Solving Multi-follower Bilevel Mixed-integer Programs via a Generalized Value Function

Onur Tavaslioglu, University of Pittsburgh, Houston, TX, 77025, United States, Oleg A. Prokopyev, Andrew J. Schaefer

We introduce a generalized value function of a mixed-integer program, which is simultaneously parameterized by its objective and right-hand side. We describe its fundamental properties, which we exploit through three algorithms to calculate it. We then show how this generalized value function can be used to reformulate multi-follower bilevel mixed-integer programming problems. We present the solution of instances that are significantly larger than those solved in the literature in terms of the total number of variables, and the number of followers. We compare our approach with an open source solver, MibS.

## 4 - Exact Multiple Sequence Alignment by Synchronized Multi-valued Decision Diagrams

Willem-Jan Van Hoeve, Carnegie Mellon University, Tepper School of Business, 5000 Forbes Avenue, Pittsburgh, PA, 15213, United States, Amin Hosseiniinasab

Sequence alignment problems appear in the context of bioinformatics, natural language processing, and financial applications, and aim to identify regions of similarity in sequences of data. While pairwise sequence alignment is tractable, optimal multiple sequence alignment is challenging in theory as well as practice. We present a new exact method that first represents all pairwise sequence alignments using multi-valued decision diagrams. These are then synchronized with an integer programming model, which we solve using a logic-based Benders decomposition. Our approach can improve state-of-the-art heuristic solvers, and outperforms the best exact methods from the literature.

## ■ WC72

West Bldg 211A

## Practice- Operations Management IV

Contributed Session

Chair: Fang Fang, California State University, Los Angeles, CA, 91801, United States

## 1 - Forward-reserve Warehouses: Why a Dynamic Selection of Items is Necessary

Rakesh Venkatasubramony, Assistant Professor, Indian Institute of Management Lucknow, IIM Road, Prabandh Nagar, Lucknow, 226013, India

Forward-Reserve warehouses are popular when small number of Stock Keeping Units (SKU) account for large number of picks. Most studies that approach the design and allocation of SKUs to forward area have static decisions. In this simulation based article, I argue for dynamic selection of SKUs to the Forward area of the warehouse, when individual demands are seasonal.

## 2 - Competition in Two-sided Market with Quality Control Strategies

Lyu Gaoyan, Peking University, No.5 Yiheyuan, Beijing, 100871, China, Lihua Chen

There are many two-sided markets with similar products. We design mechanism to explore how to cooperate and compete with competitors at the same time. Meanwhile, how to improve their product quality to attract consumers is another important factor in this mechanism. We set cooperate parameter and compete parameter to measure the degree of market competition. The result shows that, with low degree competition, both markets get less profit.



### 3 - Dynamic Return and Resale Policies for Heterogeneous Strategic Customers with Uncertain Valuations

Lan Lu, Hong Kong University of Science and Technology,  
Clear Water Bay, Kowloon, Hong Kong, Hong Kong, Qian Liu

This paper develops a model of return and resale policies with heterogeneous strategic customers who have uncertain valuations prior to purchase. The seller faces a two-period selling season, where the returned products in the first period can be resold in the second period. We characterize the seller's optimal return policies in both periods and compare two resale policies: differentiate the returned products with new products or not. We demonstrate that the seller tends to differentiate the returned products when customers are highly differentiated. Moreover, we find that the seller does not always benefit from the increase of customer valuation.

### 4 - Robust Optimization Approach to Process Flexibility Designs with Price Differentials

Shixin Wang, New York University, New York, NY, 10012,  
United States, Xuan Wang, Jiawei Zhang

We study process flexibility designs when products exhibit price differentials. We introduce the Profit Plant Cover Index (PPCI) and prove that a general class of robust measures can be expressed as functions of a design's PPCIs and the given uncertainty set, which leads to a method to compare the worst-case performance of different designs. Applying these results, we prove that under a broad class of uncertainty sets and robust measures, the alternate long chain is optimal among all long chains with an equal number of high-profit products and low-profit products. Finally, we develop a heuristic based on the PPCIs to generate effective flexibility designs when products exhibit price differentials.

### 5 - In-house vs. Outsourcing: The Effect of Volume-based Learning on Quality Competition

Yanni Ping, Drexel University, 3220 Market Street, Philadelphia,  
PA, 19104, United States, Seung-Lae Kim

This paper considers an original equipment manufacturer (OEM) who outsources finished products to a contract manufacturer (CM), where the CM, by adopting existing technology, achieves cost reduction and quality improvement through learning-by-doing. Besides the role of upstream partner, the CM also acts like a downstream competitor. We study the OEM's outsourcing strategy dynamically from both cases when competition exists and does not exist by constructing a two-period model and explore the interplay of learning, quality and cost.

### 6 - Block Ownership in Vertical Relationships in the Presence of Downstream Competition

Fang Fang, Assistant Professor, California State University,  
Los Angeles, CA, 90032, United States, Baojun Jiang, Jiong Sun

Block ownership (i.e., partial ownership) plays an important role in aligning the incentives of firms involved in vertical relationships. This paper examines the impacts of block ownership on pricing decisions, firm profitability, as well as consumer and social surplus. We show that such impacts may depend on the nature of downstream competition.

## ■ WC73

West Bldg 211B

### Practice- Robust Optimization & Applications I

Contributed Session

Chair: Jonathan David Lonski, Clemson University, Clemson, SC,  
29631, United States

#### 1 - Robust Portfolio Optimization Based on Stochastic Dominance and Empirical Likelihood

Peng Xu, Aalto University School of Business, Runeberginkatu  
22-24, Helsinki, FIN-00100, Finland

Identifying Second-order Stochastic Dominance (SSD)-efficient portfolios is of great interest to finance research where investors are routinely assumed to be rationally risk-averse in financial decision making. This paper seeks to (i) evaluate some most recent SSD optimization approaches and their out-of-sample performance, and (ii) examine if robust optimization based on SSD and Empirical Likelihood (EL) improves out-of-sample performance of these approaches. We report the results from an empirical application analyzing how robust diversification among industry portfolios using SSD and EL increases the likelihood of obtaining out-of-sample dominance over a given benchmark portfolio

#### 2 - Robust Multi-criteria Decision Making for Hesitant Behavior

Gevorg Stepanyan, PhD Candidate, University of Michigan -  
Dearborn, Dearborn, MI, United States, Jian Hu

We presents a robust multi-criteria decision making model for hesitant behavior.

### 3 - Robust Repositioning for Vehicle Sharing

Long He, National University of Singapore, Mochtar Riady  
Building, BIZ1 8-73, 15 Kent Ridge Drive, Singapore, 119245,  
Singapore, Zhenyu Hu, Meilin Zhang

Our paper discusses the operational decision of dynamic fleet repositioning for vehicle sharing. We first formulate the problem as a stochastic dynamic program to minimize the expected total repositioning cost and lost sales penalty. To solve for a multi-region system, we deploy the distributionally robust approach that can incorporate demand temporal dependence, motivated by observations from real trip data. In a real-world case study, we quantify the "value of repositioning" and compare with several benchmarks to demonstrate that the proposed solutions are computationally scalable and in general result in lower cost with less frequent repositioning.

### 4 - Mitigating Disaster-induced Transportation System Losses via Robust Optimization

Jonathan David Lonski, Clemson University, Clemson, SC, 29631,  
United States, Scott J. Mason

Recent natural disasters like Hurricane Sandy (2012) and Tropical Storm Harvey (2017) have caused \$20B+ in economic losses and necessitated \$35B+ in restoration efforts. During such disasters, it is often too late for decision makers to spend time and effort analyzing information, and weighing potential outcomes. We present our research into developing robust plans for minimizing the total cost of economic losses and reparations incurred by transportation systems during natural or human-caused disasters. We seek to improve transportation system plan resiliency via robust optimization techniques and establishing an improved, cloud-based method of data collection for use in our models.

## ■ WC74

West Bldg 212A

### Joint Session MCDM/Practice Curated: Theory and Application of the ANP

Sponsored: Multiple Criteria Decision Making

Sponsored Session

Chair: Orrin Cooper, University of Memphis, Memphis, TN, 38152,  
United States

#### 1 - An AHP Consensus Reaching Model with Both Individual and Aggregated Opinions

Qingxing Dong, Central China Normal University, Wuhan, China,  
Qi Sheng, Gaohui Cao

The Analytic Hierarchy Process (AHP) is an effective tool and has been widely used in group decision making. In this paper a new consensus reaching model based on the AHP is proposed, which considers both individual and aggregated opinions. The compatibility index can be used to determine both the individual consensus level (ICI) and the central consensus level (CCI). Then this model provides feedback suggestions to the most incompatible decision makers so they can adjust their opinions adaptively depending on their ICI and CCI in each round. The integrated adaptive consensus reaching model is constructed. Finally, a numerical example is given to verify the feasibility and effectiveness of the model.

#### 2 - Coherency and Reducing Comparisons in the ANP

Orrin Cooper, University of Memphis, Memphis, TN, 38152,  
United States

One of the perceived challenges of using the ANP is number of comparisons that need to be made to ensure the model will converge without absorbing states. There are also data quality checks that one can use to increase the confidence she has in the decision. Coherency testing can be balanced to not only test for coherency but also reduce the number of needed comparisons in an ANP model.

#### 3 - The Added Value of a Team-based Model in Preventive Healthcare Services

M Gabriela Sava, Clemson University, College of Business,  
145 Sirrine Hall, Clemson, SC, 29634, United States, Luis Vargas,  
Jerrold H. May, Jennifer Shang, James Dolan

The role and importance of preventive healthcare services has increased significantly due to the health benefits to the patient. The design of such services becomes a challenge due to the increased number of patients that would like to get more involved in the preventive decision-making process, but they don't possess all the necessary information. We propose a team-based model for designing the process of choosing the most appropriate colorectal cancer screening option. The value-added in the model is the result of the contribution of the healthcare provider to achieve beneficial patient outcomes.

#### 4 - Analogical Evaluation of the Urban Function Combination Mode of the Integrated Transportation Hub Based on AHP Fuzzy Comprehensive Evaluation Method

SiYu Tao, School of Transportation and Logistics, Southwest Jiaotong University, Chengdu, China, Feng Tao, Xinmei Chen, anjun li, Lisha Wang

This paper adopts a AHP fuzzy comprehensive evaluation for the different forms of the integrated transportation hub, the AHP model is used to establish & quantify the assessed level indicators of the urban function combination modes of the integrated transportation hub, & an index evaluation system is established to evaluate the advantages & disadvantages of different combination modes accurately. Suggestions are proposed for optimization & improvement on the evaluation results, & scientific guidance are provided for the development, construction & investment operation of the urban function of the integrated transportation hub.

### ■ WC75

West Bldg 212B

#### Online Optimization I

Contributed Session

Chair: Wenda Zhang, University of Illinois at Urbana-Champaign, Urbana, IL, 61801, United States

##### 1 - Dispatch: An Optimal Algorithm for Online Perfect Bipartite Matching with I.I.D. Arrivals

Quico Spaen, University of California, Berkeley, CA, 94709, United States, Minjun Chang, Dorit Simona Hochbaum, Mark Velednitsky

We introduce DISPATCH, a 0.5-competitive, randomized algorithm for the problem of weighted online perfect bipartite matching with i.i.d. arrivals. We prove that 0.5 is the best-possible competitive ratio. In this problem, we are given a known set of workers, a distribution over job types, and non-negative utility weights for each worker, job type pair. At each time step, a job is drawn i.i.d. from the distribution over job types. Upon arrival, the job must be irrevocably assigned to a worker. The goal is to maximize the expected sum of utilities after all jobs are assigned. Our work is motivated by the application of ride-hailing, where jobs represent passengers and workers represent drivers.

##### 2 - Online Linear Programming with Production Costs

Michael Fairley, PhD Candidate, Stanford University, Stanford, CA, 94305, United States, Yinyu Ye

We consider a sequential decision making problem where a sequence of orders arrive and we must decide to accept or decline the order before the next order is revealed. If an order is accepted then we create a production plan to supply the products by selecting suppliers to provide each product. The offline problem is a linear program and the online problem is an online linear program where the objective coefficient and constraint matrix are revealed over time. We present an online algorithm, which learns the dual prices from the columns of the previous periods and uses the dual prices to make a decision in the current period. We present simulation results that indicate that our algorithm is near optimal.

##### 3 - Model-based Sensor-selection Submodular Optimization: Performance Trade-offs

Orlando Romero, Rensselaer Polytechnic Institute, Troy, NY, 12180, United States, Sergio Pequito

Submodularity is an increasingly popular tool to address NP-hard problems defined on matroid-constrained subset cost/utility functions. Within this framework, polynomial-time approximation algorithms (such as greedy algorithms) can be implemented with theoretical worst-case guarantees. This work is motivated by sensor and actuator selection problems in the context of large-scale dynamical systems, where we show that under certain problem formulations within this context, the more well-known submodular-based bounds can be proved to be overly conservative since they fail to fully leverage the structure of the problem.

##### 4 - A Branch-and-bound Algorithm for the One-machine Problem and Delayed Precedence Constraints Variation

Wenda Zhang, University of Illinois, Urbana, IL, 61802, United States, Jason Sauppe, Sheldon H. Jacobson

The one-machine scheduling problem with release and delivery times with the minimum makespan objective often arises as a subproblem for the general job shop scheduling problem. A branch-and-bound algorithm solves the problem and its variation, which allows the presence of constraints that require a delay between the completion of one job and the start of another. This paper analyzes key components of this branch-and-bound algorithm and proposes a new heuristic and a different search strategy. Computational experiments show the modified algorithm to have substantial improvement in running time and number of iterations on instances both with and without delayed precedence constraints.

### ■ WC76

West Bldg 212C

#### Topics for Phd Students

Sponsored: Minority Issues

Sponsored Session

Chair: Karen T. Hicklin, University of North Carolina at Chapel Hill, Chapel Hill, NC, 27599-3260, United States

##### 1 - Topics for PhD Students

Karen T. Hicklin, University of North Carolina at Chapel Hill, B-24 Hanes Hall, Chapel Hill, NC, 27599-3260, United States

This panel discussion will feature early career professionals who will share advice regarding their graduate school experiences and navigating the job market.

##### Panelists

Shannon Harris, The Ohio State University, 1262 Eastwood Ave, Columbus, OH, 43203, United States

Alba Rojas-Cordova, Southern Methodist University, Dallas, TX, 75219, United States

Jessye Talley, Morgan State University, 2316 Naylor Rd SE, Washington, DC, 20020, United States

### ■ WC77

West Bldg 213A

#### Finance – Risk Management

Contributed Session

Chair: Shaofang Li, Southeast University, Jiangning District, Nanjing, 211189, China

##### 1 - Computation of Optimal Conditional Expected Drawdown Portfolios

Alex Papanicolaou, University of California-Berkeley, Mountain View, CA, 94041, United States, Lisa R. Goldberg, Ola Mahmoud

We introduce a partial differential equation approach to computing and minimizing the risk measure of Conditional Expected Drawdown (CED) of Goldberg and Mahmoud (2016). We derive a methodology that allow ones to perform function and gradient evaluation for a first-order optimization routine to a convex portfolio optimization problem for computing minimum CED portfolios. We apply this to a log-normal pricing model and show how under this framework, minimum drawdown portfolios relate to minimum variance and minimum shortfall portfolios.

##### 2 - Merging for Stabilizing Financial Networks

Aein Khabazian, University of Houston, 4796 Cullen Blvd, Houston, TX, 77004, United States, Markku Kallio, Jiming Peng

We analyze the possibility of the mergers of solvent and in-solvent banks to stabilize a financial network based on the extended Eisenberg-Noe's model where the liquidation cost is considered and the liabilities have different seniorities. We develop a model to identify the best match in the system such that the total gain obtained through the merger is maximized. A subsidized merger where the social planner provides some bail-outs to cover part of the liabilities of the insolvent bank is also considered. We use a network of major European banks to evaluate the performance of the pure merger and subsidized merger in the system.

##### 3 - Banking Sector Reform, Competition, and Bank Stability

Shaofang Li, Southeast University, No.70, Suyuan Avenue, Jiangning District, Nanjing, 211189, China, Wenping Wang

This study tests the impact of banking sector reform and competition on bank stability in 14 transition countries in 1998-2016. The results find negative relationship between the market power and bank stability, but positive relationship for bank reform. The results also suggest that the positive relationship between bank competition and stability is more pronounced if banking sector experienced higher financial development and has better financial information transparency. The effect of competition in reducing bank risk is less pronounced if the banks are exposed to higher activity restrictions and grater stringency on capital requirements, particularly in more competitive markets.

## Wednesday, 3:20PM - 4:50PM

### ■ WD01

North Bldg 121A

#### Machine Learning via a Modern Optimization Lens

Sponsored: Optimization/Optimization under Uncertainty

Sponsored Session

Chair: Dimitris Bertsimas, Massachusetts Institute of Technology, Cambridge, MA, 02139, United States

##### 1 - Optimal Clustering Trees

Agni Orfanoudaki, MIT, 77 Massachusetts Avenue, Cambridge, MA, United States, Holly Mika Wiberg, Dimitris Bertsimas

State-of-the-art clustering algorithms use heuristics to partition the feature vectors while providing little insight regarding the interpretability of each cluster. We present a new Optimal Clustering Trees algorithm that leverages mixed-integer optimization (MIO) techniques to generate interpretable and globally optimal clustering tree models. We demonstrate that our method achieves superior performance on both synthetic and real-world datasets and scales even when the number of observations is high.

##### 2 - Optimal Survival Trees

Emma Gibson, Massachusetts Institute of Technology, Dimitris Bertsimas, Jack W. Dunn, Agni Orfanoudaki

Tree-based models are increasingly popular due to their ability to identify complex relationships that are beyond the scope of parametric models. Survival tree methods adapt these models to allow for the analysis of censored outcomes, which often appear in medical data. We present a new Optimal Survival Trees algorithm that leverages mixed-integer optimization (MIO) and local search techniques to generate globally optimal survival tree models. We demonstrate that the OST algorithm improves on the accuracy of existing survival tree methods, particularly in large datasets.

##### 3 - Missing Data Imputation for Clinical Covariates with Time Series

Colin Pawlowski, Massachusetts Institute of Technology, Cambridge, MA, United States, Dimitris Bertsimas, Agni Orfanoudaki, Ying Zhuo

Missing data is a common problem in healthcare applications where researchers use EMR, claims data, and results of observational studies to apply analytics methods. We propose a family of optimization-based methods for imputation of data sets consisting of clinical covariates of patients observed over time. We derive first-order methods that find high quality solutions in minutes for data sets with 10,000s of patients and 100s of clinical covariates. We demonstrate that our method med.impute outperforms state-of-the-art methods in imputation accuracy and out-of-sample performance on downstream tasks on healthcare data sets with real and synthetic missing patterns.

##### 4 - Optimal Classification Trees with Hyperplanes are as Powerful as Classification Neural Networks

Matthew Sobieski, Massachusetts Institute of Technology, Dimitris Bertsimas, Rahul Mazumder

We investigate the modeling power of neural networks in comparison with optimal classification trees with hyperplanes (OCT-Hs). We prove that a variety of neural networks can be transformed to decision trees with hyperplanes, showing that OCT-Hs are at least as powerful as neural networks. Conversely, we show that a given classification OCT-H can be transformed to a classification neural network with the perceptron activation function, showing that these neural networks are at least as powerful as OCT-Hs, that is, OCT-Hs and these neural networks are equivalent in terms of modeling power.

### ■ WD04

North Bldg 122A

#### Algorithms for MIP Applications

Sponsored: Optimization/Integer and Discrete Optimization

Sponsored Session

Chair: Ayse Aslan, University of Groningen, Groningen, 9747 AE, Netherlands

##### 1 - Energy Optimization of a Plug in Electric Vehicle Along a Fixed Path

Bilgenur Guru, Middle East Technical University, Industrial Engineering, No: 326. Cankaya, Ankara, 06800, Turkey, Mustafa Kemal Tural, Arsham Atashi Khoei

Given an origin-destination pair and a fixed path between them, we consider the problem of determining the speed of a plug-in electric vehicle on each road segment along the path, the charging stations the vehicle will stop by, and how much to recharge at each stop so as to minimize the total amount energy consumption of the vehicle. We assume that there is a speedlimit on each road

segment which cannot be violated by the vehicle. Moreover, it is assumed that the vehicle has to arrive at the destination on or before a given time-limit. We propose a mixed-integer second order cone programming formulation for the problem and evaluate its performance. Effects of some valid inequalities are also investigated.

##### 2 - Isolation Branching: A Branch and Bound Algorithm for the K-terminal Cut Problem

Mark Velednitsky, University of California-Berkeley, Berkeley, CA, United States

The k-terminal cut problem is: Given an edge-weighted graph with k terminals, remove a minimum weight collection of edges such that there is no path between any pair of terminals. The problem is NP-hard. Although it has multiple applications, no optimization algorithms have been devised specifically for the problem. We present the first branch-and-bound optimization algorithm customized for k-terminal cut. The performance of our algorithm is demonstrated to be practical for a number of real-world instances. As a by-product, we prove that the complexity of Isolation Branching is fixed-parameter tractable with respect to the size of the optimal solution.

##### 3 - Learner Demand-driven School Timetabling

Ayşe Aslan, University of Groningen, Nettelbosje 2, Groningen, 9747 AE, Netherlands

Personalized learning in secondary schools in Netherlands offers flexibility for learners to create their own learning paths by choosing which learning activities they want every week. This leads to the emergence of demand-driven timetables in schools. We propose an integrated IP model to produce weekly demand-driven timetables for learners and teachers simultaneously.

### ■ WD05

North Bldg 122B

#### Joint Session OPT/Practice Curated: SCIP Optimization Suite: Recent Developments and Applications

Sponsored: Optimization/Computational Optimization and Software  
Sponsored Session

Chair: Ambros Gleixner, Zuse Institute Berlin, Berlin, 14195, Germany

Co-Chair: Benjamin Mueller, Zuse Institute Berlin, Berlin, 12161, Germany

##### 1 - Reinforcement Learning of Branching Strategies

Maxime Gasse, Polytechnique Montr al, Montr al, QC, Canada, Andrea Lodi

Branching decisions arguably take a central place in traditional branch-and-bound solvers. We formulate the branching problem as a 1-player game, whose ending is triggered once the instance has been solved, and where the goal is to minimize the final tree size. Under this formalism, one can use reinforcement learning to find good branching strategies, e.g. using a mix of Monte-Carlo Tree Search and deep learning (the AlphaGo approach). We will present some preliminary results on MIPLIB instances, based on an implementation that combines the SCIP and PyTorch libraries.

##### 2 - Digging for Variable Holes in MINLPs

Benjamin Mueller, Zuse Institute Berlin, Berlin, 12161, Germany, Andrea Lodi, Gonzalo Munoz

Due to the presence of nonconvex constraints in mixed-integer nonlinear programs (MINLPs), the set of feasible assignments can be disconnected even for continuous variables. The resulting forbidden regions for variables are called "holes", which can be viewed as a generalization of integrality conditions in MILP. This allows us to conceive methods for continuous variables that so far have been mainly developed for integer variables.

We study the concept of holes and their importance in a spatial branch-and-bound framework. Additionally, we show that a branching rule driven by the knowledge of holes in a nonconvex problem can have a significant impact on the performance of the MINLP solver SCIP.

##### 3 - A Branch and Price Approach for an Inventory and Routing Problem to Address the Replenishment of a Network of Automated Teller Machines

Cristian Eduardo Cortes, Universidad de Chile, Blanco Encalada 2002, Santiago, Chile, Daniel Herl, Pablo Andres Rey, Alejandro Cataldo, Leandro C. Coelho

The main goal of this study is to develop a Branch and Price method for the inventory-routing problem arising from the replenishment of an automated teller machines (ATM) network. One interesting feature of the problem is the existence of out of stocks in the inventory of the ATMs. Moreover, one additional difficulty in our pricing subproblem is the existence of column dependent rows, which means that we are forced to dynamically generate columns and rows simultaneously. We implement our B&P algorithm on the SCIP framework, obtaining promising results for selected real instances in Santiago, Chile.



**4 - Progress in the Branch-price-and-cut Solver GCG**

Marco Luebbecke, RWTH Aachen University, Operations Research,  
Kackertstr. 7, Aachen, D-52072, Germany, Michael Bastubbe,  
Christian Puchert, Jonas Witt

GCG is a solver for mixed-integer linear programs. It implements a Dantzig-Wolfe (or similar) reformulation and a full-featured branch-price-and-cut algorithm. Information on how the reformulation should be performed can be given by the user in various ways. However, GCG can and usually does detect a model structure suited for reformulation all by itself. We report on recent developments that lead to the upcoming release 3.0. This includes a completely re-designed structure detection, new cutting planes, and experimental features like deciding whether a reformulation should be applied at all and a Benders decomposition extension. We show experiments and some use cases in which we applied GCG.

**WD06**

North Bldg 122C

**Global Optimization II**

Sponsored: Optimization/Global Optimization

Sponsored Session

Chair: Akang Wang, Carnegie Mellon University, 5000 Forbes Avenue,  
Pittsburgh, PA, 15213, United States

**1 - Global Optimization Algorithm to Solve the Equilibrium-constrained Program for Estimating Random-coefficient Demand Function**

Yu-Ching Lee, National Tsing Hua University, No 101, Section 2,  
Kuang-Fu Road, Engineering Building I, Hsinchu, Taiwan,  
Cy (Chor-yiu) Sin

Recently, estimation problem of random-coefficient demand function using aggregate market level observations has been formulated as an equilibrium-constrained optimization program. This modeling technique successfully bridges the advance of nonlinear programming (NLP) solvers with important class of problem in demand estimation. NLP solvers are convenient and efficient in terms of implementation and computation for estimating demand. Nevertheless, a guarantee of global optimality is missing. In the talk we will discuss the importance of global optimality for this class of problem. Then, a global optimization algorithm will be presented to solve for a global optimal estimator.

**2 - Bilevel Optimization Problem for Preferred Boarding Groups**

Viacheslav V. Kalashnikov, Tecnológico de Monterrey, (ITESM),  
Campus Monterrey, Ave Eugenio Garza Sada 2501 Sur, Monterrey,  
Nuevo Leon, 64849, Mexico

We consider a bilevel optimization problem, in which the upper-level decisions are made by the airline's management governing the proportion of preferred boarding passes (PBP) to be available, as well as the price of the latter. The economy class passengers find Nash equilibrium at the lower level by trying to minimize their flight cost, where the individual cost function has two components: the PBP price and the expected waiting time in the line to the check-in counters. As the optimality at the lower level provides the percentage of PBPs sold to have the minimum deviation from its value in the future sales, the Markov chain stable state technique is used to solve the problem. The model has a practical value.

**3 - A Customized Branch and Bound Approach for Circle Packing**

Akang Wang, Carnegie Mellon University, 5000 Forbes Avenue,  
Pittsburgh, PA, 15213, United States, Chrysanthos Gounaris

We present a custom-built linear relaxation and an associated branch-and-bound approach for solving circle packing problems to global optimality. We utilize a novel branching scheme based on circle-circle non-overlapping constraints, and we also employ concave envelopes to tighten the feasible domain. Extensive computational studies are performed on benchmark instances and the preliminary results demonstrate our approach's superiority over the state-of-the-art general-purpose global solvers.

**4 - New Underestimator and Branching Scheme for the Global Optimization of General Nonconvex Problems**

Ishan Bajaj, Texas A&M University, 3122 TAMU, College Station,  
TX, 77843, United States, Faruque Hasan

The selection of the underestimator and branching scheme are central to the effectiveness of a branch-and-bound (B&B) algorithm. We propose to exploit a new class of edge-concave underestimators, constructed by subtracting a positive quadratic expression that overpowers all non-edge-concavities in the original function. We also propose a novel branching technique based on a univariate projection of the original multi-dimensional space into a single auxiliary space such that a function exists on this map whose global minima is the same as that of the original function. We will show the efficacy of the proposed relaxation and branching schemes with other methods in the literature.

**WD08**

North Bldg 124A

**Topics in Non-convex Optimization**

Sponsored: Optimization/Nonlinear Programming

Sponsored Session

Chair: Mert Gurbuzbalaban, Rutgers University, Piscataway, NJ, 08854,  
United States

Co-Chair: Nuri Denizcan Vanli, Massachusetts Institute of Technology,  
Cambridge, MA, 02141, United States

**1 - Local Optimality and Generalization Guarantees for the Langevin Algorithm via Empirical Metastability**

Belinda Tzen, University of Illinois at Urbana-Champaign, Urbana,  
IL, United States

We study the path-wise behavior of the discrete-time Langevin algorithm for non-convex ERM via metastability. For a given local optimum of the empirical risk, we show that w.h.p., the path either ends up outside an  $\epsilon$ -neighborhood of this optimum by a short recurrence time; or it enters by then and stays until an exponentially-long escape time. This aligns with existing literature. Firstly, recurrence time is dimension independent, like convergence of deterministic gradient descent. Secondly, escape time is consistent with the Eyring-Kramers law; i.e., the Langevin scheme visits all local minima, with exponentially-long transit time. We use this to examine local generalization and optimality.

**2 - Convergence Rate of Block-coordinate Maximization Burer-Monteiro Method for Solving Large SDPs**

Nuri Denizcan Vanli, Massachusetts Institute of Technology,  
22 Palermo Street, Cambridge, MA, 02141, United States

Semidefinite programming (SDP) with equality constraints arise in many optimization and learning problems, such as max-cut, community detection and robust PCA. Although SDPs can be solved to arbitrary precision in polynomial time, generic solvers do not scale well with the dimension of the problem. To address this issue, Burer and Monteiro proposed to reduce the dimension of the problem by imposing a low rank factorization and solve the resulting nonconvex problem. To solve this nonconvex problem, we propose a first-order method based on block coordinate ascent with exact line search. We provide convergence rate guarantees and computational results on large-scale problems.

**3 - Momentum-Based Acceleration for Non-convex Stochastic Optimization**

Mert Gurbuzbalaban, Massachusetts Institute of Technology,  
77 Massachusetts Avenue, Building 32 / Room D632, Cambridge,  
MA, 02139, United States

We consider stochastic non-convex optimization problems that arise in several applications including machine learning and the stochastic gradient Hamiltonian Monte Carlo (SGHMC) algorithm to solve them. We obtain the first finite-time global convergence guarantees for SGHMC in the context of both empirical and population risk minimization. Our results show SGHMC can achieve acceleration on a class of non-convex problems compared to overdamped Langevin MCMC approaches such as the stochastic gradient Langevin dynamics. This is joint work with Xuefeng Gao and Lingjiong Zhu.

**WD09**

North Bldg 124B

**Fairness and Transparency in Applied Operations**

Sponsored: Manufacturing & Service Oper Mgmt

Sponsored Session

Chair: Swati Gupta, PhD, Georgia Institute of Technology, Atlanta, GA,  
United States

Co-Chair: John Silberholz

**1 - Market Failure in Kidney Exchange**

Itai Ashlagi, Stanford University, Huang Engineering Center,  
475 Via Ortega, Stanford, CA, 94305, United States

We find that kidney exchange markets suffer from traditional market failure that reduce transplants by over 25%. We document that the market is highly fragmented and inefficient. We propose a model to illustrate two sources of inefficiency: hospitals do not internalize their patients' benefits and current mechanisms provide sub-optimal rewards to hospitals. Eliminating this inefficiency requires a combined approach that uses mechanisms and solves agency problems.

## 2 - Fairness Metrics in Facility Location Problems

Gireja Ranade, UC Berkeley, Atlanta, GA, Swati Gupta, Akhil Jalan, Helen Yang, Simon Zhuang

We consider the NP-hard facility location problem: given a set of facilities and a set of consumers to serve, determine a subset of  $k$ -facilities that minimizes the sum of distances from each consumer to the nearest facility. For public facilities such as hospitals, playgrounds and waste collection facilities, it is important to take equity across groups into consideration. Various equity metrics have been proposed in the literature and our work explores the tradeoffs between them.

## 3 - Fairness in Prediction Models Used by Public Service Agencies

Maria De-Arteaga, Carnegie Mellon University

The use of machine learning to assist public service agencies is both promising and concerning, with problems ranging from child welfare to criminal justice and preventive health. While at first sight many of these may appear to be traditional prediction problems, the characteristics of available data and deployment contexts give rise to several challenges that have not been sufficiently addressed in the machine learning literature. Issues include presence of unobservables, selective labels, and omitted payoff biases. This talk discusses some of these challenges and presents novel methodologies to tackle them.

## 4 - Finding Equitable Start Times for Boston Public Schools

Arthur J. Delarue, Massachusetts Institute of Technology, 77 Massachusetts Ave, Cambridge, MA, 02139, United States, Dimitris Bertsimas, Sebastien Martin

Over 80% of high schools across the U.S. begin school before 8:30AM, even though early start times have been linked to serious health issues for teenagers. Because districts cannot estimate the impact of bell time changes on the cost of their complex bus schedules, change is often impossible under a fixed budget. We present a new optimization approach for the bell time assignment problem, which takes into account transportation costs as well as the complex needs of school districts. We discuss the application of our methodology as part of our collaboration with Boston Public Schools, which led to the unanimous approval of the first new start time policy in almost thirty years by the Boston School Committee.

## WD10

North Bldg 125A

## OM in Semiconductor Manufacturing II

Sponsored: Manufacturing & Service Oper Mgmt

Sponsored Session

Chair: John W Fowler, Arizona State University, Tempe, AZ, 85287-4706, United States

Co-Chair: Lars Moench, University of Hagen, Hagen, 58097, Germany

### 1 - Design of Remote Diagnostic Networks for Semiconductor Equipment Suppliers

John W. Fowler, Arizona State University, P.O. Box 874706, Supply Chain Management, Tempe, AZ, 85287-4706, United States, Giulia Pedrielli, Esma S. Gel

With advances in information technology, service activities for expensive equipment used in semiconductor manufacturing can be performed from a remote location. This is called remote diagnostics (RD). RD has the potential to reduce maintenance and capital costs and improve productivity. We develop a queueing-location model to analyze the capacity and location problem of after sales service providers, considering the effects of RD technology. Our model optimizes the location, capacity and the type of service centers while taking congestion effects into consideration. We solve this model using a simulation optimization approach in which we use a genetic algorithm to search the solution space.

### 2 - The Importance and Trends in Central Planning – Illusion of Control

Kenneth J. Fordyce, Arkieva, 5460 Fairmont Drive, Wilmington, DE, 19808, United States

Most organizations can be viewed as an ongoing sequence of loosely coupled decisions where current and future assets are matched with current and future demand across the demand-supply network at different levels of granularity. Since the middle 1990s, enterprise-wide supply, master or central planning, whose purpose is to create a projected supply linked to detailed exit demand and synchronize the activities of the enterprise, has become a key member of this “decision suite within the Kempf-Sullivan Decision Grid. This presentation provides an overview of key trends such as increased granularity and diffusion and why it is important - even if it just creates the Illusion of control.

## 3 - Improving Intel's Supply Planning Performance Using a Proprietary Enterprise Optimization Solution Suite

Shamin Shirodkar, Intel Corp, Chandler, AZ, United States, Zhenying Zhao

As Intel has transitioned from High-Volume Low-Mix (HVLN) to High-Volume High-Mix (HVHM) manufacturing, supply planning has become much more complex & effective supply planning translates to a clear competitive advantage. In this presentation we will be sharing an enterprise suite of proprietary well integrated optimization solutions which support supply planning at Intel & in the process various advanced generic modeling concepts, innovative formulations and solving techniques will be introduced.

## WD11

North Bldg 125B

## Joint Session MSOM/Practice Curated: Smart City Operations Management

Sponsored: Manufacturing & Service Oper Mgmt

Sponsored Session

Chair: Ho-Yin Mak, University of Oxford, Oxford, OX1 1HP, United Kingdom

### 1 - The Role of Consumer Waste in Food Retail

Ekaterina Astashkina, INSEAD, Boulevard de Constance, Fontainebleau, 77305, France, Elena Belavina, Simone Marinesi

We investigate how addition of consumer food waste changes the inventory dynamics and emissions of the upstream actors. We find that consumer food waste (unlike transportation emissions) generates spillover effects on upstream tiers: higher consumer food waste prompts higher retail sales and emissions. Hence, practices that cut consumer food waste are particularly efficient in contrast to other instruments that aim to benefit the environment. Further, we find that interventions targeted to reduce travel in the attempt to lower market emissions may in fact achieve the opposite result and increase market emissions, on account of higher consumer food waste.

### 2 - Revenue Management in Parking Systems under Competition and Information Asymmetries

Xin Wang, University of Wisconsin, WI, United States, Qiao-Chu He, Yuguang Wu

We consider oligopoly pricing game in parking systems under incomplete information. Each agent (garage) has some information (forecast) about the incoming parking demand for some of the garages. They charge a price for their own garage to maximize their profit. We consider the equilibrium wherein each agent's action depends linearly on known forecasts and forms Bayes' estimator for unknown forecasts. Based on the equilibrium strategy, we further investigate the agents' incentive to share their information with others in order to get larger expected payoff.

### 3 - Peer-to-peer Crowdsourcing as an Omnichannel Retail Strategy

Ho-Yin Mak, University of Oxford, Park End Street, Oxford, OX1 1HP, United Kingdom

We study a peer-to-peer crowdsourcing strategy for an omnichannel retailer, who enlists in-store shoppers to deliver online orders in their vicinity. Using an analytical model, we investigate the effect of the crowdsourcing model on the retailer's profit and consumer surplus. We find that the favorability of crowdsourcing heavily depends on the choice of reimbursement scheme and product characteristics.

## WD12

North Bldg 126A

## Practice- Marketing I

Contributed Session

Chair: Frank Hage, Technical University of Munich, Production and Supply Chain Management, Munich, 80333, Germany

### 1 - Optimal Bundling Strategy for a Retail Platform under Agency Selling

Shengming Zheng, University of Science & Technology of China, 96 Jinzhai Road, School of Management, Hefei, 230026, China, Yugang Yu, Fuqiang Zhang, Xiaolong Guo

Bundling strategy has been widely adopted by online retail platforms under agency selling. We study the optimal bundling strategy for a retail platform through which two independent manufacturers distribute their products. The manufacturers first set their product prices and then the platform decides whether to offer the bundled product or not and the price for the bundled product if it offers a bundle. By analyzing this two-stage Stackelberg game, we find that the platform will adopt the bundling strategy only when the manufacturer's product prices are above a threshold. Additionally, the manufacturers will set high prices to induce the platform to offer bundled products.

## 2 - Mental Accounting in Consumer Inventory Problem with Uncertain Benefit

Haonan He, University of Science and Technology of China, Hefei, 61820, China

Newsvendor problems describe a situation in which the vendor needs to predict the demand by a buyer when a fixed unit profit is predetermined. But sometimes, the vendor can effectively affect the demand, that is, when he is also the buyer. This paper first considers how a consumer's mental accounting behavior affects whether consumer reaches a theoretically prespecified optimal inventory level when the unit profit is not fixed and how to exacerbate and mitigate potential judgment inaccuracies. The result shows that changes to the benefits affect inventory more strongly and lead to more deviation than to the cost. Besides, inventory could increase even when the volatility of demand increases.

## 3 - Double Auctions for Truthful Information Sharing in Sales and Operations Planning

Frank Hage, Technical University of Munich, Production and Supply Chain Management, Munich, 80333, Germany, Martin Grunow

We study a sales and operations planning problem. Operations persons are responsible for production sites and have private information on production costs. Sales persons are responsible for customer markets and have private information on customer demand. Due to function-oriented bonus schemes, both parties have conflicting interests: While operations persons aim to minimize production and inventory costs, sales persons aim to maximize turnover. Both parties have an incentive to misrepresent their private information, which leads to inefficient capacity allocation and lower profitability. To address this problem, we develop an iterative double auction for capacity allocation.

## ■ WD14

North Bldg 126C

### Joint Session MSOM/Practice Curated: Healthcare Operations

Sponsored: Manufacturing & Service Oper Mgmt/Service Operations

Sponsored Session

Chair: Sukriye Nilay Argon, University of North Carolina, Chapel Hill, NC, 27599, United States

Co-Chair: Serhan Ziya, University of North Carolina, Chapel Hill, NC, 27599, United States

#### 1 - Who is Next: An Empirical Study of Patient Prioritization in an Emergency Department

Zhankun Sun, City University of Hong Kong, Kowloon, Hong Kong, Jeff Hong, Li Wenhao

In the emergency department (ED), priority scores are assigned to patients at triage based on their acuity levels. However, using operational data from more than 150,000 patient visits, we find that doctors may deviate from this priority sequence, and within each priority class, patients may not be served in a first-come-first-serve manner. Our analysis shows that when selecting the next patient to treat, doctors prioritize patients who are more likely to be discharged after treatment at ED when many ED beds are occupied by boarding patients, in an effort to avoid further access block to the ED.

#### 2 - How to Manage Doctor Appointments with a Shared Medical Appointment Option

Nazli Sonmez, London Business School, Regent's Park, London, NW1SN, United Kingdom, Kamalini Ramdas, Sarang Deo

Shared medical appointments are an alternative to traditional one-on-one appointments for routine care of chronic diseases that offer an innovative, interactive approach to healthcare delivery. They are not widely used even though there is a high potential. To adopt this new healthcare delivery method, the service providers must make an upfront decision on how to allocate service capacity. We develop a model that will incorporate what we learn about how patients make trade-offs while choosing an appointment, when offered two different appointment types using the data from a healthcare provider. This model will provide insight into how many appointments from each type need to be scheduled.

#### 3 - Equilibrium Behavior of Patients Served by a Dual Practice Physician

Lerzan E. Ormeci, Koc University, Dept of Industrial Engineering, Rumeli Feneri Yolu, Istanbul, 34450, Turkey, Dimitrios Andritsos, Yiannis Dimitrakopoulos

We consider a physician who has a dual practice in public and private sectors. We model this system as two M/M/1 queues with a coupled server. The server alternates between the queues with exponential rates. The system has three levels of decisions: First, government provides the main rules for having a dual practice, which may limit the time she spends in her public and private offices and regulate the private service fee. Second, the physician decides on how much time she will

spend in each practice and the private fee to maximize her revenue. Finally, patients decide on the office to visit to maximize their utility which is a function of their waiting time, value of service and private fee.

#### 4 - Modelling the Use of Patient Activation Measure (PAM) in Chronic Care Management

Evrin D. Gunes, Koc University, Rumeli Feneri Yolu, Sariyer, Istanbul, 34450, Turkey, Lerzan E. Ormeci, Odysseas Kanavetas, Christos Vasilakis

We develop a Markov Decision Process framework to manage care for individual patients with multiple chronic conditions through a complex care hub. Complex care provision influences the evolution of Patient Activation Measure (PAM), an indicator for healthy behavior, which affects the evolution of health state of patients. We define a general model where the transition probabilities and the rewards are time dependent parameters. Then, we explore optimal and heuristic policies which maximise the welfare for static parameters. Through numerical experiments we explore the performance of alternative policies that focus on managing more complex patients or improving activation of all patients.

## ■ WD15

North Bldg 127A

### New Topics in Demand Learning and Assortment Planning

Sponsored: Manufacturing & Service Oper Mgmt/Service Operations

Sponsored Session

Chair: Victor Araman, American University of Beirut, Beirut, Lebanon

Co-Chair: Rene A. Caldentey, The University of Chicago, Chicago, IL, 60637, United States

#### 1 - Crowdvoting New Product Introduction

Victor Araman, American University of Beirut, Lebanon, Rene A. Caldentey

Launching new products into the marketplace is a complex and risky endeavor that companies must continuously undertake. In this paper, we consider a seller who has the ability to first test the market and gather demand information before deciding whether or not to launch a new product. In particular, we consider the case in which the seller sets up an online voting system and offers multiple versions of the product - differentiated through their quality levels and prices - for potential customers to vote on. We investigate the optimal design of such a crowdvoting system in order for it to provide an effective demand forecast and allow the seller to identify which versions if any to commercialize.

#### 2 - Reputation Formation in Social Networks

Mohamed Mostagir, University of Michigan, Ann Arbor, MI, 48109, United States, Asuman Ozdaglar, James Siderius

Reputation is one of the main drivers that sustains relationships between consumers and firms. This work generalizes the reputation literature—which typically assumes sequential arrivals of agents—to a network setting. We show how a firm can manipulate the learning process of agents in a network so that they never learn the true state of the world (for example, that the firm intentionally provides low quality service or that a news outlet provides false news). We then characterize those societies that are immune to manipulation and those that are not, and suggest potential remedies for the latter.

#### 3 - Dynamic Assortment Planning under Nested Logit Models

Xi Chen, New York University, 44 W. 4th St, NYU KMC Room 8-50, New York, NY, 10012, United States, Yining Wang, Yuan Zhou

We study a stylized dynamic assortment planning problem, where for each arriving customer, the seller offers an assortment of substitutable products and customer makes the purchase among offered products according to a nested logit model. The goal of the seller is to maximize the expected revenue, or equivalently, to minimize the worst-case expected regret. We propose a lower and upper confidence bound algorithm with an aggregated estimation and establish the corresponding regret bound. One advantage of our policy is that our regret does not depend on the number of products.

#### 4 - Learning Customer Preferences from Personalized Assortments

Yifan Feng, University of Chicago, 5807 South Woodlawn Avenue, Chicago, IL, 60637, United States, Rene A. Caldentey, Christopher Ryan

A company wishes to commercialize the best version of a product out of a menu of available alternatives. The company does not know customers' preferences over the set of alternatives and relies on a voting system that allows potential buyers to vote for their preferred version. Under a general ranking-based choice model framework, we study how to dynamically customize each individual voter's choice set, so as to identify the top-ranked alternative with a fixed probabilistic confidence level, while using a minimal number of votes.



■ **WD16**

North Bldg 127B

**Economic Modeling**

Contributed Session

Chair: Fei Qin, Shippensburg University, John L. Grove College of Business, 1871 Old Main Drive, Shippensburg, PA, 17257, United States

**1 - A Spatial Model of Ride Hailing**

Cemil Selcuk, Cardiff University, Aberconway Building, Colu, Cardiff, CF10 3EU, United Kingdom

We build a spatial model to study the selection and performance of price and commission policies for a ride-sharing platform. We show that a flexible commission policy is more effective in matching demand and supply than a flexible price policy, especially if the platform does not have many cars at its disposal. Without flexible commissions, the platform resorts to price hikes to prevent excess demand; however such interventions not only distort the unconstrained demand and lower profits, but also do a poor job in spreading drivers across the city. In contrast, with a flexible commission policy the platform can spread the cars around without distorting the demand and running into any bottlenecks.

**2 - A Marketplace for Data: An Algorithmic Solution**

Anish Agarwal, Massachusetts Institute of Technology, Cambridge, MA, United States, Munther Dahleh, Tuhin Sarkar

We aim to create a data marketplace; a robust matching mechanism to efficiently buy and sell data while optimizing social welfare and maximizing revenue. Data is a unique asset: it is replicated at zero marginal cost; value is inherently combinatorial i.e. value of a dataset depends on what other data is available; value for data vary widely between firms; authenticity of data cannot be verified a priori. Hence, setting prices for a collection of datasets with correlated signals is non-trivial. Our proposed marketplace provides a complete algorithmic solution combining concepts from algorithmic market design and online optimization.

**3 - Strategic Inventories in a Supply Chain with Downstream Cournot Duopoly**

Xiaowei Hu, PhD Student, University of Wisconsin-Milwaukee, Milwaukee, WI, 53212, United States

We present a game-theoretic supply chain model, in which a manufacturer supplies products to a pair of identical Cournot duopolistic retailers. We show that the strategic inventory carried out by the retailers under dynamic contract is Pareto-dominating for the manufacturer, retailers, consumers, the channel, and the society as well. We also find that retailer's strategic inventory can be eliminated when the manufacturer commits wholesale contract or inventory holding cost is too high. In comparing the cases with and without downstream competition, we also show that the downstream Cournot duopoly undermines the profits for the retailers, but benefits all others.

**4 - Engineering Economic Valuation of Blockchain Technology for Petroleum Industry Supply Chain under Uncertainty**

K. Jo Min, Iowa State University, 3004 Black Engineering, Department of Industrial & Ames, IA, 50011-2164, United States, John Jackman, Farshad Niayeshpour

Much interests in blockchain technology applicable to petroleum industry supply chain notwithstanding, there has been little analytical investigation of the critical attributes of the blockchain technology such as the value of immutability, irrefutability, traceability, scalability, and transparency. In this paper, we aim to show how such attributes can be valued, in the context of petroleum industry supply chain, from a perspective of stochastic optimal control. In particular, we will show what the underlying assets may be and how strike prices can be found via real options approach. Illustrative numerical examples based on the fluctuation of the petroleum product prices will be presented.

■ **WD18**

North Bldg 128A

**Metaheuristics**

Contributed Session

Chair: Jiemin Xie, University of Hong Kong, 91B Pokfulam Road, Pokfulam, Hong Kong, 999077, China

**1 - An Effective Memetic Algorithm for the Boolean Quadratic Programming Problem with Generalized Upper Bound Constraints**

Daiqiang Yin, Northwestern Polytechnical University, Xi'an, China, Yang Wang, Abraham Punnen

We propose an effective memetic algorithm for solving the NP-hard boolean quadratic programming problem with generalized upper bound constraints. The main ingredients of the proposed algorithm include a reverse learning based population initialization, a uniform combined with greedy rule guided crossover operator, an adaptive tabu search method and a rank based population updating.

Experiments on problem instances with up to 6000 variables demonstrate the effectiveness of the proposed algorithm.

**2 - Genetic Algorithm for Planar Capacitated Single Allocation Hub Location Problem**

Derya Ipek Eroglu, Middle East Technical University, Ankara, 06450, Turkey, Duygu Pamukcu, Cem Iyigun

In this study, Genetic Algorithm (GA) has been implemented to Planar Capacitated Single Allocation p-Hub Location Problem. In this problem, the objective is to locate the hubs and assign the supply and/or demand points to hubs so as to minimize the total of distribution and transfer costs. If Euclidean Distance is used as a distance measure calculating the cost, the problem becomes nonlinear. Therefore, GA has been implemented to the problem. Computational studies have been performed regarding solution quality and runtime, and solutions are compared with these of Discrete Capacitated Single Allocation p-Hub Location Problem.

**3 - A Study on Two-stage Genetic Algorithm for the Mixed-integer Linear Programming with Non-linear Objective Functions**

Kiseok Sung, Gangneung-Wonju National University, 150 NamWon-ro, Wonju, 26403, Korea, Republic of

We propose a genetic algorithm for MILP with nonlinear objective function. This algorithm consists of two stages of a hierarchical evolutionary process. At higher levels, integer variables evolve and linear variables evolve at lower levels, where we use a method that maintains the feasibility of a linear variable according to a linear equation constrained by a given integer chromosome. This method uses null-space projection and bound shift techniques. I have been coding the proposed method in MATLAB and tested the sample problems.

**4 - Revenue Management for Dual Channel Retailer Using Randomized Decomposition Based Evolutionary Algorithm**

Shrinath Dakare, Indian Institute of Technology-Kharagpur, Meghnad Saha Hall of Residence, Kharagpur, 721302, India, Vishal Gupta, Manoj Kumar Tiwari

We consider integrated price optimization, inventory replenishment and demand fulfillment problem for a dual channel retailer who has adopted cross channel fulfillment strategy. Demand function is modeled using MNL model with price dependent attraction function. The problem so formulated is non-linear and non-convex that we solved using Randomized Decomposition based Evolutionary Algorithm. We compare the results obtained with that of recently proposed Randomized Decomposition based Neighborhood Search. We also demonstrate that price optimization problem could efficiently be solved using intelligent search heuristics, technique which has largely been ignored for such problems.

**5 - A Heuristic Approach to Passenger-oriented High-speed Train Schedule Model**

Jiemin Xie, The University of Hong Kong, Hong Kong, China, Shuguang Zhan, S.C. Wong, S.M. Lo

A better railway timetable for high-speed railway, HSR, can provide a more convenient service to passengers, which may attract more consumers transferring from domestic air flights and cars. In this study, a schedule model, which minimizes the total path cost of passengers and is subjected to both standard train schedule and passenger path choice constraints, is proposed to generate conflict-free and convenient schedule plan. A heuristic HSR scheduling algorithm is proposed to solve our model. This heuristic algorithm is based on the decomposition approach and the iterative approach. The South China HSR network is used to test the optimality, efficiency, and applicability.

■ **WD19**

North Bldg 128B

**Joint Session RMP/Practice Curated: New Applications of Revenue Management and Pricing**

Sponsored: Revenue Management &amp; Pricing

Sponsored Session

Chair: Joline Uichanco, University of Michigan, Ross School of Business, Ann Arbor, MI, 48109-1234, United States

**1 - Price Markdowns to Induce Customers to Opt Out of Free Returns**

Sajjad Najafi, Ross School of Business, University of Michigan, 701 Tappan Ave, Ann Arbor, MI, 48109, United States, Izak Duenyas

In this paper, we consider a firm offering a product to a set of consumers who can return it over a grace period of time. The firm aims at finding the optimal return policy to improve its total expected revenue.

**2 - Life Cycle Pricing of Multiple Differentiated Products**

Hongmin Li, Arizona State University, WP Carey School of Business, Dept of Supply Chain Management, Tempe, AZ, 85287, United States

This paper considers the centralized pricing problem of a firm managing multiple substitute or differentiated products. Demands of these products undergo a diffusion process and customers choose among the products, with the choice probability of each product given by the logit model. We examine the firm's optimal pricing problem in this context.

**3 - Dynamic Pricing and Replenishment for Seasonal and Regular Products**

Oben Ceryan, LeBow College of Business, Drexel University, Philadelphia, PA, 19103, United States

We consider a firm that offers two substitutable products that differ in how their inventories are managed, a seasonal product with a fixed initial quantity that allows dynamic price adjustments but no replenishments, and a regular product with a static price that can be periodically replenished. We study the impact of these asymmetries on optimal dynamic pricing and replenishment decisions and utilize the insights gained to develop a simple-to-implement and effective heuristic policy.

**4 - Competitive Revenue Management with Sequential Bargaining**

Yuanchen Li, Purdue University, 2192 Tortuga Lane, West Lafayette, IN, 47906, United States, Qi Feng, J. George Shanthikumar

We study the role of bargaining in competitive revenue management. The seller firms each have some fixed initial stocks and compete to sell to a random arrive stream of potential buyers who are heterogeneous in product valuation. We fully characterize the equilibrium outcome, which depends on the length of the selling season and the initial stock levels. When the selling season is up to three periods, the seller with a lower stock level is weakly preferred by an incoming buyer. When the selling season is longer than three periods, the seller with a higher stock level may win the competition.

**■ WD21**

North Bldg 129B

**Pricing and Revenue Management**

Contributed Session

Chair: Kimitoshi Sato, Kanagawa University, Yokohama, Kanagawa, Japan

**1 - Managing Opportunistic Consumer in Retail Operations**

Tolga Aydinliyim, Associate Professor, Baruch College, One Bernard Baruch Way, Department of Management, New York, NY, 10010-5585, United States, Mehmet Sekip Altug, Aditya Jain

Considering "honest-customers versus "renters, we assess the merits "targeted-refunds and "menu-of-refunds proposals retailers use to mitigate opportunistic consumer returns. Relative to benchmarks with "no-renters (Su, 2009) and "uniform-refunds, we find that the menu-of-refunds proposal with a low restocking-fee can separate customer types when leftover/returned units must be significantly marked down.

**2 - The Effect of Internet Bots on Dynamic Pricing of Perishable Products**

Kimitoshi Sato, Kanagawa University, Yokohama, Kanagawa, Japan

We study the problem of a firm that sells perishable products with a dynamic pricing scheme in the presence of internet bots. The bots automatically check for changes in price every few seconds and hold the price during short period (e.g. 24 hours). Reservations by the bots does not generate revenue for the firm if payments are not completed and will temporarily increase the selling price. In this research, we formulate a dynamic pricing model in presence of the bots and derive an optimal pricing policy. Then we show how does the behavior of bots affect the firm's expected revenue as well as the optimal price trend.

**■ WD22**

North Bldg 130

**Practice- E-Business/Commerce I**

Contributed Session

Chair: Roger William Baugher, TrAnalytics, LLC, Johns Creek, GA, 30097, United States

**1 - The Moderating Effect of Reputation and Presentation on Trust Transfer of Trusted Third Party**

Cong Cao, University of Wollongong, Wollongong, NSW 2522, Australia, Jun Yan, Mengxiang Li

Based on experimental data, this paper not only shows the significant influence of trusted third party (TTP) on consumers' behavior, but further explains its trust transfer function in the online shopping environment. Moreover, it also reveals moderator variables of the trust transfer, namely the reputation and presentation of TTP. The research results show that the certification service provided by TTP with high reputation can significantly improve the degree of consumer trust in enterprises. The concrete and detailed description and presentation of TTP services can effectively enhance consumers' cognition of TTP services and therefore influence their behavioral intention.

**2 - End-to-end Inventory Replenishment Model**

Yuanyuan Shi, University of Washington, 6319 65th Avenue NE, Seattle, WA, 98115, United States, Di Wu, Meng Qi, Rong Yuan, Yuhui Shi, Max Shen

Traditional inventory models often assume a predict-then-optimize paradigm. A prediction model which depicts the demand uncertainty is built then an optimization model is applied to solve for optimal inventory decisions based on the forecasting. However, the criteria by which we train the prediction model often differs from the ultimate criteria on which we evaluate them. In this research, we focus on building an end-to-end inventory replenishment model which simultaneously learns the probabilistic info of multiple uncertainty sources such as demand, lead time, while making replenishment decisions that directly capture the cost-based objective.

**3 - Competitive Intelligence Analysis from Customer Online Concerns of Series Products for Engineering Design**

Jian Jin, Beijing Normal University, No. 19, Xijiekouwai street, Beijing, 100875, China, Qian Geng, Ping Ji

Online concerns inform valuable messages to customers, dealers and product designers. Conventional studies mainly focus on the sentiment analysis of online opinions and few explore their capacities on comparison of series products. In this study, a framework is presented to highlight shared pros and cons of series products by mining online concerns. Customer opinions of specific features across series products are initially extracted and clustered to identify similar concerns. Then, an optimization problem is formulated to sample a few representative sentences for designers. This study aims to integrate big consumer data for competitive intelligence analysis in market driven product design.

**4 - Current State of Railroad Yard Technology**

Roger William Baugher, President, TrAnalytics, LLC, Johns Creek, GA, 30097, United States

Given the high cost of improvements to a rail yard's infrastructure, railroads are investigating and implementing new control technology and enhanced information systems to improve performance and reduce costs. These efforts will be discussed and a summary presented.

**■ WD23**

North Bldg 131A

**Quantitative Methods in Financial Engineering**

Sponsored: Finance

Sponsored Session

Chair: Qi Wu, The Chinese University of Hong Kong, Hong Kong

Co-Chair: Lingfei Li, Chinese University of Hong Kong, Shatin, N. T, Hong Kong

**1 - A Multidimensional Hilbert Transform Approach for Barrier Option Pricing and Survival Probability Calculation**

Jie Chen, Chinese University of Hong Kong, Shatin, N. T, Hong Kong, Liaoyuan Fan, Lingfei Li

We propose a novel approach for pricing discretely monitored multi-asset barrier options and computing joint survival probability in multivariate exponential Levy asset price models using multidimensional Hilbert transform. Our method features exponential decay in the discretization parameter and various numerical examples are provided to demonstrate its efficiency in both 2D and 3D cases.

**2 - Parsimonious Learning of Tail Dynamics**

Qi Wu, City University of Hong Kong, Kowloon, Hong Kong, Xing Yan

We propose a semi-parametric machine learning approach to study the serial dependence of conditional distribution in asset returns, motivated by the problem of tail risk forecast. This approach combines the merits of a novel parameterization of conditional quantile function with the Long short-term memory (LSTM) sequential neural network. Comprehensive empirical study shows that the dynamics of return distribution is not always auto-regressive in nature; further, drivers of higher moments' serial dependencies could contain risk factors that are independent of those responsible for volatility clustering. These findings should have important implications for financial risk management.

### 3 - Robust Bounds of Default Probabilities in Financial Networks

Dohyun Ahn, The Chinese University of Hong Kong, Shatin,  
N. T., Hong Kong

We focus on firm-specific default probabilities in the Eisenberg-Noe network model with random shocks. In particular, we are interested in finding their robust bounds when financial networks are not fully observed. We first identify shock amplification caused by the network structure, which allows us to define the firm-specific default probabilities in financial networks. Using mixed-integer linear programming, we then obtain two kinds of robust bounds: one from a specific bank's perspective and the other from regulators' perspective. Also, we address asymptotic behaviors of those bounds when the shock size decreases. The applicability of those results is illustrated via numerical examples.

### 4 - Dynamic Programming, Progressive Hedging Algorithm and Machine Learning

Xin Huang, PhD Student, The Chinese University of Hong Kong,  
Shatin, Hong Kong, Duan Li

Dynamic programming often fails due to unavailability of analytical cost-to-go functions. In this research, we first solve the primary problem approximately by applying progressive hedging algorithm to associated scenario trees. Next we adopt neural networks to find mappings from states to values as approximated cost-to-go functions. We then update these approximated cost-to-go functions backward for all successive two stages by minimizing the gap between the prediction from preceding approximated function and that from the principle of optimality. This process iterates until achieving desired precision.

## ■ WD24

North Bldg 131B

### Practice- Productivity Improvement in Manufacturing

Contributed Session

Chair: Douglas Thomas, NIST, 100 Bureau Drive, Gaithersburg, MD,  
20899-8603, United States

#### 1 - The Direction of Causality between Personnel Management Practices and Productivity

Juha Eskelinen, Researcher, Aalto University, Runeberginkatu  
22-24, Helsinki, 00100, Finland, Ossi Aura, Guy Ahonen, Timo  
Kuosmanen

Causal relationship between personnel management practices and productivity remains ambiguous. This longitudinal study combines survey data from Finnish small and medium size enterprises in manufacturing with productivity indicators for years 2008-2016 (17100 observations). Controlling for firm specific factors such as capital intensity, we find that measures regarding management development, work environment and content are associated with increase in future productivity. In contrast, measures like increasing non-financial employee benefits follow high productivity and do not precede it.

#### 2 - The Impact of Patents on Manufacturing Productivity

Anand Kandaswamy, Economist, NIST, Washington, DC, 20008,  
United States

The traditional economics models in manufacturing usually look at factors like plant and equipment spending, worker education, and research and development funding to measure changes in productivity levels. What they tend to ignore is the role of innovation in driving productivity. Patents have traditionally been recognized as an excellent proxy for levels of innovation. Using data from 2004 to 2014, the author focused on six key manufacturing industries and created a model in R Studio that tries to determine the relative importance of innovation (as represented by patent activity) with respect to the more traditionally accepted components of economic productivity.

#### 3 - The Effect of Flow Time on Productivity and Production

Douglas Thomas, Economist, NIST, Gaithersburg, MD, 20899-  
8603, United States

Operations management strategies incorporate flow time and inventory turns as a metric for tracking and improving performance; however, there is limited understanding regarding the impact of reducing flow time. This paper examines the impact that flow time has on productivity and production, measured using the multifactor productivity index and manufacturing value added. A total of 6 models are presented and two simulations. The results suggest that flow time reflects and impacts productivity and production both within an industry and between industries. Moreover, the results are consistent with using flow time as a metric to identify industry level bottlenecks and improve productivity.

#### 4 - Experimental Investigation of Stratasys J750 Polyjet Printer: Effects of Printing Parameters on Bending Strength

Xingjian Wei, Graduate Student, Texas A&M University, College  
Station, TX, 77843, United States, Abhinav Bhardwaj, Zhijian Pei,  
Bruce Tai

Additive Manufacturing (AM) has found significant applications in the engineering of prototypes as well as functional parts. These advances have resulted in the origination of high-resolution, multi-material printers such as the Stratasys J750: world's first full-color, multi-material 3D printer. In this research,

we analyze the effects of printing parameters on the bending strength of samples printed by the Stratasys J750 printer. The results from this study would be valuable to research institutions and businesses leading high-resolution, multi-material 3D printing of polymers.

#### 5 - The Motivation of Capital-giving in Crowdfunding Market: A Self-determination Theory Perspective

Xiang Yuan, Tongji University, Shanghai, China, Hongwei Wang,  
Yuan Meng

How to promote crowd-funding results successfully are crucial to crowdfunding projects. The results of crowd-funding projects are determined by investors' subjective behavior, which is triggered by some certain motivations. Through identifying different motivation modes mainly influenced by the project description, it will be beneficial to identify the investment intention of each investor. In this paper, based on the self-determination theory, we first create the corpus targeting different motives by means of the text mining method. Then, we classify the project description and project investment options. Last, we conduct an econometric model to examine the effect of investor's motives.

## ■ WD25

North Bldg 131C

### Service Inventory Management

Sponsored: Service Science

Sponsored Session

Chair: Seongkyoon Jeong, Arizona State University, Tempe, AZ,  
United States

#### 1 - Applying Time Buffer Management to Lean Service Design

Xiaofeng Zhao, University of Mary Washington, Fredericksburg,  
VA, 22406-7272, United States

Theory of constraint-based buffer management is widely used to protect the system's output from disruptions. The research employs queuing methods to calculate the time buffer size in lean service operation. It discusses computable expressions for the mean and the variation of waiting time. The approach can be implemented to conduct what-if analysis.

#### 2 - Research on Supplier Evaluation in Service Procurement Based on Fuzzy Soft Set

Jie Xu, Pittsburgh, PA, 15213, United States

The use of fuzzy soft sets can flexibly deal with multiple projects, different indicators, and uncertain service procurement items. Considering the experts' case evaluation of the supplier's various indicators, and based on the deterministic evaluation when considering the expert rating, the supplier's negative (risk) factors and hesitation factors in each index are considered. Combining the expert's affirmative scoring, negative and hesitant scores on supplier indicators, using triangular fuzzy numbers to represent the experts' determination and negation of suppliers, and establishing an improved triangular fuzzy soft-package service procurement supplier evaluation model.

#### 3 - Optimal Inventory and Redesign Strategies in Resolving Part Obsolescence

Zhenyang Shi, Student, Shanghai Jiao Tong University, 1954  
Huanshan Road, Shanghai, 200030, China, Shaoxuan Liu

We study the joint part inventory and product redesign decisions for a manufacturer facing part obsolescence problem. Product redesign, and inventory control approaches such as last time buy, are two focal strategies in obsolescence resolution. We establish an optimal stopping model with additional decisions to investigate when should product redesign be initiated and how should part procurement and inventory be managed, during product life cycle after obsolescence. We show the optimality of a threshold policy for redesign choice and well-structured policies including the target interval policy for inventory control.

#### 4 - Understanding Service Innovation Introduction and Diffusion through the Lens of the Economic Order Quantity Model

Seongkyoon Jeong, Arizona State University, Tempe, AZ,  
United States, Adegoke Oke

Unlike tangible manufactured products, services have unique characteristics, which motivate the need to understand how service innovations are introduced and how they diffuse or percolate targeted markets. Using novel data of daily usage of online game services in South Korea, we find that service innovations in such online game industry appear to follow the saw-tooth patterns typically observed in the traditional inventory profile model of economic order quantity. We address what types of service products or innovations experience this phenomenon and what determines this type of introduction and diffusion profile.



## ■ WD26

North Bldg 132A

### Design and Operation of Interdependent Critical Infrastructure Systems

Sponsored: Service Science

Sponsored Session

Chair: Ann Suhaimi, Northeastern University, Somerville, MA, 02145, United States

Co-Chair: Jacqueline Griffin, Northeastern University, Boston, MA, 02115, United States

#### 1 - Design and Control of Resilient Interdependent Infrastructures

Hana Khamfroush, University of Kentucky

In this talk I explain a general analytic model that captures multiple types of interdependency among nodes of interdependent infrastructures. Given an initial failure this model allows us to analyze the impact of different network topologies, different types of coupling, different failure/attack models, and different ways of choosing initial spreaders on the propagation of failures in such networks. Based on our observations, we propose design guidelines for resiliency of interdependent infrastructures. We also propose a new metric of centrality designed for interdependent networks. We will compare the preciseness of the proposed metric with the standard centrality metrics.

#### 2 - Cyber-physical Attacks Recovery in Interdependent Power and Communication Systems

Wei Sun, Assistant Professor, University of Central Florida, Orlando, FL, 32816, United States

The increasing threats from natural disasters and cyber attacks on cyber and physical systems (CPS) could trigger catastrophic events and cause tremendous damage to physical systems. The interdependency between CPS drastically increase the complexity of enhancing CPS security and resiliency. This talk will introduce the adaptive and resilient restoration strategies that coordinate the recovery efforts between power and communication systems. Challenges and recommendations will be discussed on building a secure and resilient nation, ultimately self-healing from cyber-physical attacks.

#### 3 - Examining the Joint Role of Load Shedding and Emergency Services Effectiveness during Critical Events

Ann Suhaimi, Northeastern University, Somerville, MA, 02145, United States, Jacqueline Griffin

Load shedding refers to power outages that occur by design by the utility companies to ensure that certain areas will not experience disruption in power especially during natural disaster. While load shedding commonly addressed in many studies, the effects of load shedding, especially on the greater population is still absent. This study aims to estimate the stress on EMS deployment that occurs after power is lost due to load shedding using Vehicle Routing Problem that is the core of EMS fleet deployment. We develop a model accounting for human cost to understand the relationship between power loss, load shedding, and EMS response time.

#### 4 - System of Systems Modeling for Incentive Policy Design in Promoting Electric Vehicle Transport

Chao Lei, University of Illinois at Urbana-Champaign, Liqun Lu, Yanfeng Ouyang

Encouraging travels with electric vehicles (EVs) has been recognized as an effective and economical approach to reducing greenhouse gas emissions. Economic concerns and travel conveniences are two crucial factors affecting EV ownership and usage. We propose a system of systems (SOS) model to help the government decide the optimal EV purchase incentivization and charging infrastructure deployment while considering the interdependency among the transportation, power, and environment systems and the EV market. Charging infrastructure deployment is modeled as a bi-level problem accounting for users' travel choices. An iterative-based algorithm is developed to solve the proposed model.

## ■ WD27

North Bldg 132B

### Information Systems II

Contributed Session

Chair: Xiahua Wei, University of Washington, Bothell, WA, 98011, United States

#### 1 - The Impact of Platform Levers on Ecosystem Development: The Case of Twitter Hashtags

Sameer Borwankar, PhD Student, Purdue University, West Lafayette, IN, United States

Social media platforms generate revenue through advertising or transaction based charges. Hence, growing and managing the active users is at the core of the

platform management. In our study, we focus on the impact of platform features on attracting new users. Our empirical context is the hashtags used on Twitter to discover and contribute to user-generated content around a specific theme. In that context, we ask following questions 1. Do hashtags play a role in attracting new users? 2. Do different types of hashtags have a different impact on attracting new users? 3. Do these users continue to use the platform? We analyze more than 13 million tweets generated in 2016 and 2017 to address these questions.

#### 2 - A Reputation and Credit-based Retrieval System for Hybrid Wireless Networks

Yung-Ting Chuang, National Chung Cheng University, Min-Hsiung Township, Chia-Yi County, Taiwan

Currently, trust in information accessed via the Internet depends on its unbiased centralized systems to ensure high efficiency and low cost, but we cannot guarantee such centralized systems to remain unbiased forever. As mobile devices are becoming the primary devices for communications, the network has shifted to hybrid wireless network (HWN). Thus, I propose a system for HWN which: 1) resolves the censorship issues; 2) addresses forwarding attacks; 3) encourages cooperation incentives; 4) ensuring low overhead and high retrieval rates. After implementing this system, I plan to measure my system against other existing retrieval systems, and confirm its effectiveness.

#### 3 - Data Breach Disclosure Laws and Digital Security Conscientiousness

Raviv Murciano-Goroff, Graduate Student, Stanford University, 579 Serra Mall, Stanford, CA, 94305, United States

In 2002, California enacted a law requiring that companies publicly disclose data breaches. To evaluate the impact of data breach notification laws, I collected data on the decisions of 2,185 public companies regarding when to update their web server software and apply security patches during the two years before and after the California legislation was signed. Using a difference-in-difference strategy, I find that the data breach notification law in California caused firms based there to use web server software that was 12.06% newer.

#### 4 - A Clustering Based Decision Tree Approach for Risk Assessment of Information Security in Smart Cities

Yana Yuan, PhD Candidate, Northwestern Polytechnical University, Xi'an, 710129, China, Huaqi Chai

The emergence of new information technologies poses challenges to information security in smart cities. Risk is the most prominent challenge. In this paper, we analyze the impact factors of information security in smart cities and evaluate the risks that these factors bring to information security. We aim at establishing a new evaluation index system and building a risk assessment model based on Ward's method and decision tree. Then we present an empirical study on risk assessment of information security in 15 smart cities. We provide a data-based and intelligent method to assess the risks of information security, and give solutions to address the challenges for information security in smart cities.

#### 5 - A Game-theoretic Model of Protecting Interdependent Systems with Incomplete Information

Fei He, Texas A&M University - Kingsville, MSC 191, MEIE Dept., 700 University Blvd., Kingsville, TX, 78363, United States

Securing a complex system in the face of adversary attacks is challenging because of many factors, such as the coupling between constituent systems, the adaptiveness of attackers, and uncertainty of both systems and attackers. We propose a new game-theoretic model of protecting interdependent systems with incomplete information. By analytically and numerically solving the model, we analyze the effects of system interdependency pattern, and the uncertainty of attacker's attack preference to defense strategies at Nash equilibria. The research provides new insights for system design, and optimal defense strategy for infrastructures such as telecommunication networks, and power grids.

#### 6 - The Effect of Prefunding on Crowdfunding Success

Xiahua Wei, University of Washington, Bothell, 18115 Campus Way NE, Box 358584, Bothell, WA, 98011, United States, Weijia You, Ming Fan, Yong Tan

We investigate the effect of prefunding on the success of crowdfunding. Using a daily panel dataset from a large online crowdfunding platform, we examine the dynamic effects of prefunding on fund raised and different types of backers, and find that prefunding attracts lottery backers and non-lottery backers differently. We also use counterfactual decomposition to distinguish the prefunding effect and the effect of project characteristics on funding outcomes, which helps us uncover the kind of projects that succeed through prefunding.

## ■ WD28

North Bldg 221A

**Practice- Transportation-Operations IV**

Contributed Session

Chair: Zhen Tan, Cornell University, Ithaca, NY, 14850, United States

**1 - Multi-methodological Approach for Risk Mitigation Strategy Selection in the Trucking Industry: A Truck Drivers Perspective**

Krishna Kumar Dadsena, Indian Institute of Technology Kharagpur, Kharagpur, Vs Hall, B. 243, IIT Kharagpur, Kharagpur, 721302, India, Sarada Prasad Sarmah, V. N. A. Naikan

This study aims to identify the operational risks induced by the truck drivers' job satisfaction criteria, and to select the most suitable risk mitigation strategy on managing the operational efficiency of the trucking industry. The approach based on the systematic application of survey-based analysis and fuzzy theory is used to develop a novel algorithm to support the strategy selection process.

**2 - Dynamic Subsidy-pricing Models for Multi-modal Transportation Integration: The One Belt-one Road Strategic Context**

Tanmoy Kundu, National Taiwan University, Taipei, Taiwan, Jiuh-Bing Sheu

One Belt-One Road (OBOR) is a regional/international developmental initiative recently initiated by the Chinese government. One of the challenges being faced in the OBOR operations is the ineffective utilization of the multiple modes of transportation. Huge subsidy to one mode of transportation is leading to the cannibalization of the other. Hence, this work offers various dynamic subsidy-pricing models associated with the dynamic multimodal transportation networks along the OBOR corridors.

**3 - An Efficient Iterative Algorithm for the Integrated Optimization of Train Timetabling and Maintenance Task Scheduling**

Yongxiang Zhang, Southwest Jiaotong University, Chengdu, 610031, China, Qiyuan Peng, Andrea D'Ariano, Bisheng He

Track maintenance tasks need to be scheduled to retain the railway tracks in an appropriate state. However, the planning of track maintenance activities is interrelated with the train timetabling process. In this work, train timetabling is optimized together with maintenance task scheduling to solve potential planning conflicts and to allocate the available railway capacity more efficiently to the scheduled services. A new mixed integer linear programming model is formulated and an efficient iterative algorithm is proposed to find near-optimal solutions within a short computation time. The experimental results show that the proposed algorithm outperforms previously proposed approaches.

**4 - The Pareto-improving Hybrid Fare Scheme with Heterogeneity in Commuter's Scheduling Flexibility**

Yili Tang, Hong Kong University of Science and Technology, Academic Building, Room 3595, Hong Kong, China, Hai Yang

This paper proposes a hybrid fare scheme (HFS) combining a fare-reward scheme (H-FRS) and a uniform fare scheme (H-UFS) by considering the heterogeneous commuter's scheduling flexibility in transit bottleneck model. It aims at reducing peak-hour congestions with alternative options catered for various commuters. In H-FRS, a commuter is rewarded with a free ride during shoulder periods after taking a number of paid rides during the central period in peak hours. The H-UFS determines a uniform fare. The preliminary results demonstrate that the HFS is not only revenue-preserving but also Pareto-improving. An optimally designed hybrid scheme can achieve a reduction in total time costs by at least 25%.

**5 - Effect of Information Delay on Real-time Routing and a Potential Remedy**

Zhen Tan, Nottingham University Business School (China), Ningbo, 14850, China, Jamol Pender, H. Oliver Gao, Xiaoning Zhang

In dynamic routing, travel time information is often delayed and hence inaccurate because of challenges in data collection and sensor working principal. This inaccuracy can misguide motorists and result in unstable traffic patterns that exacerbate congestion. To alleviate this negative effect, we analyzed the potential of providing drivers with real-time en-route air pollution information (in addition to travel time) using a new queueing model. Results of our theoretical and numerical analysis indicate that provision of real-time air pollution information can help stabilize traffic. We verified this benefit by traffic simulation of the George Washington Bridge based on real-world data.

## ■ WD29

North Bldg 221B

**Urban Public Transport**

Sponsored: TSL/Urban Transportation

Sponsored Session

Chair: Yanshuo Sun, Florida State University, Tallahassee, FL, 20742, United States

**1 - Multi-period Line Planning in Urban Public Transportation**

Guven Sahin, Sabanci University, Faculty of Engineering and Natural Sciences, Istanbul, 34956, Turkey, Amin Ahmadi, Ralf Borndörfer, Malte Ranken, Thomas Schlechte

Line planning in urban transportation is involved with determining the number and routes of the lines along with their frequencies given an underlying physical transportation network. In traditional line planning, demand is considered as static while fleet-related constraints are secondary. We solve a multi-period line planning problem with integer programming formulations that consider dynamicity of the demand. Multi-period solutions outweigh the single-period solutions with respect to system-wide service levels. Indeed, single period solutions when combined with each other may not even be feasible due to suboptimal allocations of vehicles among lines.

**2 - Regulation of Public Transit Monopoly under Asymmetric Information**

Yanshuo Sun, Florida State University, Tallahassee, FL, 20742, United States, Qianwen Guo

Contrary to the dominant assumption, we study how to regulate a monopolistic transit operator with unknown cost parameters. A benchmark model which assumes complete cost information is proposed and solved analytically. Then government's decisions based on prior estimates of cost parameters are evaluated and the welfare loss due to the incomplete information is thus identified. Next, an incentive-compatibility regulatory policy which induces the operator to report its true parameter is proposed. Finally, the derivation of the optimal policy is provided and its properties are analyzed. Thus, this study provides an effective tool for designing regulatory policies and evaluating practices.

**3 - Uncertainty Quantification of Dynamic Urban Transit System State Estimates in Big Data Applications: An Information Space Projection Approach**

Jiangtao Liu, Arizona State University, Tempe, AZ, 85282, United States, Xuesong Zhou

This talk aims at a modeling framework to systemically account for the multi-source sensor information in urban transit systems to quantify the estimated state uncertainty. By developing a system of linear equations and inequalities, the information space is generated based on the available heterogeneous sensor data. Then, a number of projection functions are introduced to match the relation between the unique information space and different system states of interest. Finally, different state estimate uncertainties are quantified by calculating its maximum state range.

**4 - Passenger Trajectory Generation and Characterization using Modern Datasets**

Xiaoyan Xie, Cole des Ponts ParisTech, Champs-sur-Marne, France, Fabien Leurent

Passenger trajectory generation and characterization along a line on a Public Transport (PT) network was still a difficult task, as it must capture not only the complexity of trip building and route choice on the network; but also the heterogeneity in walking and waiting behaviors related to individual characteristics and the topological complexity of each station. Fortunately, over the last decade, the emerging modern data from automatic observation systems improved this task. However, traditional data modeling approaches were challenged. Based on the state-of-the-art review about passenger trajectory rebuilding and characterizing approaches, this paper proposed an approach to generate passenger trajectory based on smartcard data on a PT network. It is applied to a real case study in Paris. Passenger trajectory is characterized using the model output. Passenger in-station and on-network value of times (VoT) are appraised.

**5 - A Cumulative Service State Representation for the Pickup and Delivery Problem with Synchronized Transfers**

Monirehalsadat Mahmoudi, Arizona State University, Tempe, AZ, United States, Tie Shi, Yongxiang Zhang, Xuesong Zhou

In this research, in order to solve the pickup and delivery problem with time windows and synchronized transfers, we construct multi-dimensional state-space-time networks and apply a dynamic programming to solve a shortest path problem on the constructed networks. In order to handle a large set of passengers, we develop the traditional cluster-first, route-second approach. We also develop a continuous time approximation approach using cumulative arrival, departure, and on-board count diagrams to effectively assess the dynamic system performance and guide the search.

## ■ WD30

North Bldg 221C

### Practice – Shipping & Transportation Operations & Management I

Contributed Session

Chair: Qingcheng Zeng, Dalian Maritime University, School of Transportation Management, Dalian, 116026, China

#### 1 - Revenue Management in Ocean Shipping

Andres Iroume, Revenue Analytics, Atlanta, GA, United States,  
Michael Seelhorst

Container shipping companies face many of the same issues addressed by traditional revenue management (RM): perishable inventory, demand uncertainty and customers with different price sensitivities, among others. Historically, operations research based decision support systems have been implemented in this industry, including empty container repositioning, terminal operations, disruption management and others. Today, some of the first revenue management systems are being implemented. We discuss nuances and similarities with previous applications of RM.

#### 2 - Bi-level Optimization Method to Minimize Externalities by Means of Eco-transfer Staging Areas in Urban Cores

Mario E. Arrieta-Prieto, Graduate Research Assistant, Rensselaer Polytechnic Institute, Troy, NY, 12180, United States,  
Abdelrahman Ismael, Carlos Rivera-González, John E. Mitchell

Changes in urban population combined with the rise of e-commerce have had tremendous impacts on sustainable supply chains at urban cores. This paper proposes a methodology to decide optimal location of on-street staging areas in urban cores. By using a bi-level optimization problem the authors were able to capture how the agents involved in the decision pursue different objectives. In freight systems the public sector aims to maximize social welfare while the private sector looks for maximizing profit. The result of the research exhibits a formulation and a case study scenario in Manhattan that allows the evaluation of on-street staging areas from both the private and the public sector perspective.

#### 3 - Modelling the AGV and ALV System in Automated Container Terminals

Qingcheng Zeng, Dean, Dalian Maritime University,  
Linghai Road 1, Dalian, Dalian, 116026, China

This paper addresses the impact of the number of operations on the terminal efficiency based on AGV and ALV transport systems. Performance indicators of AGV and ALV transport system is obtained by queuing models, where AGV transport system is modelled by a closed queuing network and ALV transport system is modelled by a mixed queuing network. We also developed a cost model to investigate the present values of total cost of AGVs and ALVs, including operation cost, capital cost and labour cost. Numerical experiments indicate that the efficiency of ALVs and AGVs. Sensitive analysis shows the impact of the number of buffers and vehicle travelling speed on terminal efficiency.

## ■ WD31

North Bldg 222A

### Practice- Rail Transportation I

Contributed Session

Chair: Manuel Fuentes, Universidad Rey Juan Carlos, Camino del Molino, 5, Fuenlabrada, 28943, Spain

#### 1 - A Capacity Estimation System for High-speed Railway: An Integrated Approach Considering Railway Traffic and Rolling Stock Utilization

Haiying Li, Prof., Beijing Jiaotong University, Shangyuan Cun No 3, Beijing, 100044, China, Zhengwen Liao, Ying Wang, Xinyi Li

A capacity estimation approach considering both the passing capacity of railway open track segments and stations, as well as the holding and the circulation of rolling stocks is introduced in the presentation. A MIP model which jointly optimizes the timetabling, track assignment and rolling stock circulation problems is proposed to generate a saturated integrated plan. For solving the MIP model, a pressure testing method is embedded in a time-rolling algorithm framework for generating a whole-day train timetable. Based on the algorithm, a decision support system with the user interface is developed and applied in a case study on Beijing-Tianjin intercity railway.

#### 2 - Research on the Risk Fuzzy Evaluation and Control Measures of China's Rail Transportation Projects Based on Economic Sensitivity

Xu Yan, Southwest Jiaotong University, Chengdu, China  
National United Engineering Laboratory of Integrated and Intelligent Transportation, Chengdu, China, Qiyuan Peng, Jie Liu, Yong Yin, Yongxiang Zhang

This paper construct a multi-level risk evaluation system based on the sources of

risk analyses in China's rail transportation projects. Then an improved fuzzy comprehensive risk evaluation model is established in order to evaluate the risks of projects from the perspective of economy and efficiency, which combining economical sensitivity analysis method with expert scoring method to determine the weight of each level's index. Then the model verification is carried out with two examples of China's rail transportation projects. The results from multiple angles is consistent with the actual situation and the risk control measures are put forward according to it.

#### 3 - Railway Crew Scheduling with Semi-flexible Timetables

Ulrich Thonemann, Universität zu Köln, Wirtschafts und Sozialwissenschaftliche Fakultät Albertus Magnus Platz, Köln, D-50923, Germany, Christian Raehlmann

We investigate the impact of coordinating the timetable and the crew schedule in an operational freight railway system. Usually both problems are solved sequentially - resulting in suboptimal schedules with long idle times for the train drivers. We coordinate the timetable and the crew schedule by adding flexibility to the timetable. We introduce small time windows, that allow to shift entire trains forwards and backwards by discrete time periods. We solve our model with a column generation heuristic and test it on three real datasets. Our results show large reductions in idle time and cost.

#### 4 - Integrated Crew Scheduling & Crew Rostering Model for Rapid Transit Networks

Manuel Fuentes, Universidad Rey Juan Carlos, Camino del Molino, 5, Fuenlabrada, 28943, Spain, Luis Cadarso

Solving Crew Planning Problem sequentially, by tackling first the Crew Scheduling and then the Crew Rostering problems independently, usually leads to suboptimal solutions. Instead, facing the problem without splitting it into two may improve the global solution. However, this is often impractical when using exact methods, due to the complexity of the problem. We propose a heuristic approach for solving the integrated crew planning problem for rapid transit networks, where the schedules are usually daily repeated and the crews are sequenced in rotating rosters.

## ■ WD32

North Bldg 222B

### Transportation-Freight

Contributed Session

Chair: Peng Sun, K hne Logistics University, Gro er Grasbrook 17, Hamburg, 20457, Germany

#### 1 - Freight Demand Synthesis with Mode Choice: Combined Estimation Procedure

Lokesh Kumar Kalahasthi, Graduate Student, Rensselaer Polytechnic Institute, Troy, NY, 12180, United States,  
Jose Holguin-Veras, John E. Mitchell

Freight Demand Synthesis (FDS) is the process of estimating freight demand from the available data such as traffic counts, cost matrix, productions, and attractions; bypassing the need for an extensive data collection efforts. This research develops a combined model for FDS that incorporates the estimation of modal split between rail and truck. A gravity model is adopted for the estimation of trip distribution; a binary logit model for modal split between rail and truck; and Noortman and van E's model is used for empty trips. This research serves as a potential tool for transportation planners in evaluating various policy outcomes.

#### 2 - Stochastic Drayage Scheduling Problem with Time Windows

Samaneh Shiri, UPS, Baltimore, MD, United States,  
Nathan Huynh, ManWo Ng

This work studies the drayage problem which involves transporting containers in the hinterland of an intermodal terminal. It relaxes the assumption of the deterministic duration of activities in drayage operation. Two chance-constrained programming models were developed with the following assumption: 1) only the mean and variance of activities are available, and 2) the mean as well as the lower and upper bounds of activities are available. To keep the problem tractable, the chance constraints are converted to their deterministic equivalents using Cantelli's and Hoeffding's inequalities. The models were solved using optimization software CPLEX and reactive tabu search algorithm.

#### 3 - The Impact of Mass Transport on the Design of Multimodal Two-tier City Logistics Systems

Pirmin Fontaine, Technical University of Munich, Arcisstrasse 21, LST Minner, Munich, 80333, Germany, Teodor Gabriel Crainic, Ola Jabali, Walter Rei

We build on the service network design problem of a two-tier city logistics system where the goods are transported from distribution centers at the city border to satellites in the city from where the final distribution is done. Additionally, to classical trucks, we focus on the impact of mass transportation (e.g., trams) in such a system. We use a service-based integer programming formulation for the resulting multi-mode service network design problem with resource management. Decomposition techniques are used to solve the problem efficiently. The numerical results give insights on the advantages and disadvantages of the different transportation modes and what influences on the fleet structure.



#### 4 - Optimization Problem of Parcel Delivery Coordinating a Truck with Drones

Xin Wang, Tsinghua University, Shenzhen, 518055, China,  
Mingyao Qi

With the emergence of technologies, a new distribution method of deploying the unmanned aerial vehicles or drones to support the parcel delivery gradually exerts its advantages. A new idea of using a drone in conjunction with a traditional delivery truck to distribute parcels is discussed in earlier literatures. Different from the existing work, we propose a new distribution mode of a truck with several drones and provide a mathematical programming model aiming to find the optimal routing and scheduling of the multiple vehicles.

#### 5 - An Adaptive Large Neighborhood Search Heuristic for the Time Dependent Profitable Pickup and Delivery Problems with Time Windows

Peng Sun, Kuhne Logistics University, Grosser Grasbrook 17,  
Hamburg, 20457, Germany, Lucas P. Veelenturf, Mike Hewitt,  
Tom van Woensel

In this paper, we study the time-dependent profitable pickup and delivery problem with time windows. In this problem, each request consists of a pickup and delivery location, a profit is collected from the visit to its pickup. A limited amount of vehicles with a capacity limit are available. The profit of a request can be collected at most once. Time-dependent travel times are considered to capture road congestion. The objective is to determine a set of tours that maximize the difference between the collected profits and the total traveling cost. An adaptive large neighborhood search is proposed. Results show its effectiveness in finding good-quality solutions on the instances with up to 75 requests.

### ■ WD34

North Bldg 223

#### Game Theory III

Contributed Session

Chair: Timothy Murray, University of Illinois, Champaign, IL, 61820, United States

##### 1 - Schrodinger Nim

Mark J. van den Bergh, Leiden University, Ravenhorst 59, Leiden,  
2317AG, Netherlands

In the field of combinatorial game theory, many beautiful results are known for two-player, deterministic, perfect information games, of which Nim is a prime example. In this talk, we will discuss a non-perfect information variant of Nim. Employing results from non-cooperative game theory, we assess the probability of the starting player being the winner for various sizes of piles, and compare the results to the classic version of Nim.

##### 2 - What if Hotelling Firms Can Mass Customize

Alireza Yazdani, University of Oregon, 1208 University Street,  
Eugene, OR, 97403, United States, Eren Basar Cil,  
Michael Pangburn

We study product-design and price competition between two mass-customizing firms that serve consumers with varying tastes and finite reservation prices on a Hotelling linear city. By comparing equilibrium results in settings with and without mass customization, we show that mass customizers prefer markets exhibiting extreme (high or low) levels of consumers' fit sensitivity, whereas traditional firms are better off when facing moderate fit sensitivity. We also establish that competition with mass customization may lead to lower profits and consumer surplus, suggesting that regulators should closely evaluate whether to facilitate industry investments in customization technologies.

##### 3 - Effects of Limited Trust on the Price of Anarchy of Random Repeated Games

Timothy Murray, University Illinois at Urbana-Champaign,  
Champaign, IL, 61820, United States, Jugal Garg, Rakesh Nagi

We examine Leader-Follower Repeated Games of 2 players on payoff matrices randomly generated from arbitrary. We explore three concepts of Limited Trust (rather than altruism) and their effects on the Price of Anarchy, both theoretical and empirical.

### ■ WD35

North Bldg 224A

#### Data-driven Analysis for Air Transport

Sponsored: Aviation Applications

Sponsored Session

Chair: Yulin Liu, University of California-Berkeley, 107 McLaughlin Hall, Berkeley, CA, 94709, United States

##### 1 - Predicting Actual Aircraft Trajectory with Deep Mixture Density Recurrent Neural Networks

Yulin Liu, University of California-Berkeley, 107 McLaughlin Hall,  
Berkeley, CA, 94709, United States, Mark M. Hansen,  
Michael O. Ball, David J. Lovell

Reliable aircraft trajectory prediction, whether in a real-time setting or for analysis of counterfactuals, is important to the efficiency of the aviation community. We propose an end-to-end deep learning framework that consists of a Long Short-Term Memory (LSTM) encoder and a mixture density LSTM decoder to predict aircraft trajectories based on last filed flight plans, wind conditions, and convective weather. The encoder network extracts features from the flight plans, and the decoder network learns the joint distribution of the state of an aircraft from meteorological conditions. Beam search and filtering algorithms are used to stabilize the prediction results in the inference phase.

##### 2 - Physics Based Learning for Simulation and Prognostic of Aircraft Dynamical System

Yang Yu, Postdoctoral Research Associate, Arizona State  
University, Tempe, AZ, United States, Houpu Yao, Yongming Liu

This study proposes the concept of physics-based learning, a hybrid approach based on data-driven learning and physical models, as a computationally efficient method for the simulation of aircraft dynamics. The physics-based learning integrates the underlying physics of dynamical systems into learning models such as neural networks to reduce the training and simulation costs. The application of physics-based learning for simulating aircraft dynamics is demonstrated using a recently introduced physics-aware network known as the deep residual recurrent neural network (DR-RNN) on a Boeing 747-100 aircraft.

##### 3 - Denoising and Risk Identification of Bird Strikes in Civil Aviation Based on Complementary Ensemble Empirical Mode Decomposition

Chen Zhang, CASTC, Beijing, China

Bird strikes are considered as one of the important factors threatening to the safety of civil aviation. In this paper, a new application based on complementary ensemble empirical mode decomposition (CEEMD) was introduced. With the data of bird strikes from 2004 to 2013, it was split into a set of intrinsic mode functions (IMFs) and a residue. During the process of CEEMD decomposition, more features had been extracted that bird strikes were prone to influence by intermittent cyclicity. What's notable is that the MHIs always appeared in September. These findings provided a theoretical basis to early warning and better measures taken for bird strikes risk management.

### ■ WD36

North Bldg 224B

#### Practice- Inventory Management

Contributed Session

Chair: Yixuan Xiao, City University of Hong Kong, 83 Tat Chee Avenue, Kowloon, 1, Hong Kong

##### 1 - Capacity Expansion with a Bundled Supply of Capacity Attributes

Mohammad Ebrahim Arababian, University of Washington, Seattle,  
WA, 98105, United States, Shi Chen, Kamran Moinszadeh

We study the well-known problem of expanding capacity of server attributes in a cloud company where supply of attributes is bundles. We consider a cost minimization problem in a continuous review, finite horizon setting. Furthermore, the best server configurations to be deployed each cycle are studied

##### 2 - Managing Perishable Inventory Systems with Multiple Age-differentiated Demand Classes

Shouchang Chen, Zhejiang University, Hangzhou, China,  
Yanzhi Li, Yi Yang, Weihua Zhou

In this paper, we consider a periodic-review inventory system with perishable products. In the market, there are different demand classes; each can be characterized by its different lost-sale cost and freshness requirement. By establishing some new properties of multimodularity, we partially characterize the structure of the optimal policy. Based on optimality analysis, we design several efficient approximation approaches. Numerical studies show that our heuristic policy outperforms the traditional heuristics proposed by prior literature.

### 3 - Determining Optimal Parameters for an Expediting Policy under a Service Level Constraint

Simon Hoeller, University of Cologne, Albertus-Magnus-Platz, Cologne, 50923, Germany, Raik Oezsen, Ulrich Thonemann

We consider a periodic review inventory system with stochastic demand, deterministic lead times, back-ordering, and the option to move outstanding units forward in the replenishment pipeline. The objective is to minimize inventory holding and expediting costs per period subject to a minimum service level constraint. We consider a generalized base-stock policy where outstanding units are expedited when the inventory level drops below a certain threshold. We develop structural properties and present an efficient procedure to determine optimal policy parameters. In a numerical study, we show that the expediting policy offers substantial savings compared to the classical base-stock policy.

### 4 - An Aggregation-based ADP Approach for the Periodic Review Model with Random Yield

Ulrich Thonemann, Universität zu Köln, Wirtschafts und Sozialwissenschaftliche Fakultät Albertus Magnus Platz, Koeln, D-50923, Germany, Michael Voelkel, Anna-Lena Sachs

A manufacturer places orders periodically for products that are shipped from a supplier. Orders may get damaged with some probability, i.e. the order is subject to random yield. The manufacturer may track its orders to receive information on damages and to place additional orders. We solve this model with stochastic demand, tracking cost and random yield in all periods to optimality. We propose a novel aggregation-based approximate dynamic programming algorithm and provide solutions for larger instances for which it is not feasible to obtain optimal solutions. We analyze the effect of dynamic tracking and develop a heuristic that takes tracking costs into account to solve even larger instances.

### 5 - A Newsvendor Analysis with Carbon Emission Regulations

Sungyong Choi, Assistant Professor, Yonsei University, College of Government and Business, 1 Yoneseidae-gil, Wonju, 26493, Korea, Republic of

This paper aims to provide an optimization model for operational efficiency in individual firms considering various types of carbon emission regulations. More specifically, this study assumes that customer demand is given as a probability distribution. Under this circumstance, I formulate newsvendor models including carbon emission regulations and then derive practical implications for the policymakers in carbon emission regulations. Then, I analyze the models to provide closed-form solutions and conduct a sensitivity analysis for the impacts of model parameters on the optimal solutions through a comparative static analysis. All analytical results are reconfirmed by numerical analysis.

### 6 - Inventory Management under Corporate Income Tax

Yixuan Xiao, City University of Hong Kong, 83 Tat Chee Avenue, Kowloon, Hong Kong, Zhan Pang

Corporate income tax is a significant cost for companies and an important input into many corporate decisions. Corporations use after-tax earnings to reinvest in their core business and pay out dividends. We propose a framework to study a firm's inventory decisions under taxation in multi-accounting periods where each accounting period consists of multiple ordering periods. We show that in the backlog model under a convex tax or in the lost-sales model under a flat-rate tax and mild conditions, a state-dependent base-stock policy is optimal. We also examine the static effect and intertemporal effect of tax on a firm's inventory decisions.

## WD37

North Bldg 225A

### Applied Probability in Machine Learning and Optimization I

Sponsored: Applied Probability

Sponsored Session

Chair: Chang-Han Rhee, Centrum Wiskunde and Informatica, Amsterdam, 1018 MZ, Netherlands

### 1 - Approximating Data-driven Joint Chance-constrained Programs via Uncertainty Set Construction

Zhiyuan Huang, University of Michigan, Ann Arbor, MI, 48109, United States, Jeff Hong, Henry Lam

We discuss a statistical framework to integrate data into robust optimization, based on prediction set learning and a simple data-splitting validation scheme that achieves finite-sample statistical guarantees on the feasibility of the underlying uncertain constraints. We demonstrate several features of the framework, including a dimension-free sample size requirement for the feasibility guarantees and the capability to self-improve existing solutions in terms of both optimality and feasibility.

### 2 - Offline Multi-action Policy Learning: Generalization and Optimization

Zhengyuan Zhou, 160 Comstock Circle - Unit 106002, Stanford, CA, 94305, United States, Susan Athey, Stefan Wager

The unprecedented growth of easily accessible user-specific data has welcomed the exciting era of personalized decision making, an ubiquitous paradigm that has been revolutionizing many areas of operations research (e.g. health care, Internet advertising, product recommendation, public policies). The central problem in personalized decision making lies in learning from observational data a good policy, which provisions decisions based on each individual's distinct set of characteristics. In this work, we study the general offline policy learning problem and provide a principled framework to learn an effective policy from data.

### 3 - The Nearest Neighbor Information Estimator is Adaptively Near Minimax Rate-optimal

Jiantao Jiao, Stanford University, CA, United States, Weihao Gao, Yanjun Han

We analyze the Kozachenko-Leonenko (KL) nearest neighbor estimator for the differential entropy. We obtain the first uniform upper bound on its performance over Holder balls on a torus without assuming any conditions on how close the density could be from zero. Accompanying a new minimax lower bound over the Holder ball, we show that the KL estimator is achieving the minimax rates up to logarithmic factors without cognizance of the smoothness parameter  $s$  of the  $H_2$ -holder ball for  $s \in (0, 2]$  and arbitrary dimension  $d$ , rendering it the first estimator that provably satisfies this property.

### 4 - Data Driven Distributionally Robust Optimization via Optimal Transport: Algorithms and Applications

Fan Zhang, Stanford University, 450 Serra Mall, Stanford, CA, 94305, United States, Jose Blanchet, Yang Kang, Karthyek Murthy

In this talk, we are going to explain why data-driven distributionally robust optimization (DRO) is an important class of stochastic optimization problems by showing that it encompasses popular estimators in machine learning. We will provide optimal algorithms under general DRO formulations. In particular, we will prove that solving a DRO problem of an affine decision model is not harder than solving its non-robust counterpart. We will also show some estimates of the optimal transport rules. Finally, we will demonstrate empirically that our proposed methodology is able to improve upon popular machine learning estimators.

## WD39

North Bldg 226A

### Joint Session APS/Opt-Uncert: Robust and Dynamic Stochastic Optimization

Sponsored: Applied Probability

Sponsored Session

Chair: Saumya Sinha, University of Washington, Seattle, WA, 98195, United States

### 1 - A Utility Uncertainty Approach to Multiattribute Bayesian Optimization

Raul Astudillo, Cornell University, Ithaca, NY, 14850, United States

We consider multi-attribute Bayesian optimization, where each feasible design is associated with a vector of attributes that can be evaluated via a time-consuming computer code, and each vector of attributes is assigned a utility according to a decision-maker's implicit utility function.

We propose a sampling policy that maximizes the expected utility of the design chosen by the decision-maker, where her choice is based on the policy's sampling-based attribute vector estimates. In contrast with existing approaches for multi-attribute optimization that focus on estimating a Pareto frontier, our approach leverages prior information about the decision-maker's preferences.

### 2 - A Distributionally Robust Capacity Planning Model for Optimizing Access Delay in Surgical Services under Limited Information

Mohammad Zhalechian, PhD Student, University of Michigan, 1205 Beal Avenue, Ann Arbor, MI, 48109-2117, United States, Mark P. Van Oyen

We develop a capacity allocation framework that reserves OR time slots for different types of surgeries (department, duration, and urgency) in the complex network in our partner hospital. Urgent patients must be scheduled for surgery with much shorter access delay targets than elective ones. Due to the uncertainty in surgical demand, we develop a distributionally robust optimization model that assumes only the moment information of surgical demand.

**3 - Robust Countable-state Markov Decision Processes**

Saumya Sinha, University of Washington, Seattle, WA, 98195,  
United States, Archis Ghatge

Policy iteration is a standard method for solving robust Markov decision processes. For the countable-state case, however, convergence of the algorithm has not been established. Also, an as-is implementation of the method is not possible since it calls for an infinite amount of computation in each iteration. We present an approximate policy iteration algorithm that performs finitely implementable variants of policy evaluation and policy improvement. We prove that the value functions of the sequence of policies produced by this algorithm converge monotonically to the optimal value function. The policies themselves converge subsequentially to an optimal policy.

**4 - Feedback-based Tree Search for Reinforcement Learning**

Emmanuel Ekwedike, Tencent AI Lab, Bellevue, WA, United States  
Emmanuel Ekwedike, Princeton University, Princeton, NJ,  
United States, Daniel Jiang, Han Liu

Inspired by recent successes of Monte-Carlo tree search (MCTS) in a number of artificial intelligence (AI) application domains, we propose a model-based reinforcement learning technique that iteratively applies MCTS on batches of small, finite-horizon versions of the original infinite-horizon Markov decision process. We provide the first sample complexity bounds for a tree search-based reinforcement learning algorithm.

**5 - Analyzing and Provably Improving Fixed Budget Ranking and Selection Algorithms**

Di Wu, Georgia Institute of Technology, 755 Ferst Drive, NW,  
Atlanta, GA, 30309, United States, Enlu Zhou

We study the fixed budget ranking and selection problem, where the goal is to maximize the probability of correct selection (PCS) under a fixed simulation budget. First, we characterize the convergence rate of PCS for several classes of algorithms, and reveal that a constant initial samples size only amounts to a sub-exponential (or even polynomial) convergence rate. Then, we improve two state-of-the-art algorithms: OCBA from simulation optimization and successive rejects (SR) from best-arm identification. Our algorithms are guaranteed to achieve an exponential convergence rate, as is shown by finite-sample bounds on the PCS. Further, the improvement is validated using numerical experiments.

**■ WD41**

North Bldg 226C

**Practice - Decision Support Systems & Applications I**

Contributed Session

Chair: Juri Yanase, Complete Decisions, LLC, 10517 Springbrook Ave.,  
Baton Rouge, LA, 70810, United States

**1 - A Minimum Cost Consensus Model for Social-network Group Decision-making Problems with Incomplete Linguistic Preference Relations**

Dong Cheng, Xi'an Jiaotong University, Xi'an, 710049, China,  
Zhili Zhou

In this study, we propose a minimum cost consensus framework in social-network group decision-making with incomplete linguistic preference relations. First, a uninorm-based iterative procedure is presented to estimate the missing preference values. Next, we obtain the user weights by analyzing the tie strength and topology structure of their social network. Then, inconsistent users are identified through both the consistency and consensus measures. To help them reach a consensus with the minimum adjustment costs, an optimization-based consensus model is built to provide customized recommendations to them. Finally, the validity of the proposed method is verified by an example.

**2 - Optimal Pricing and Ordering Strategy in a Single Supplier Group Purchasing Problem with a Newsvendor Framework**

Abdollah Mohammadi, UNC Charlotte, 532 Lex Dr., Charlotte, NC,  
28262, United States, Ertunga Ozelkan

Procurement cost account for a significant percentage of the total cost in a business entity. Group purchasing is a procurement strategy that helps companies save in their purchasing cost. In this research we are considering a group purchasing problem where a single supplier offers a quantity discount pricing schedule and retailers should decide about their price and ordering policy to maximize their profit in a single period problem. Through theoretical analysis we find out the optimal result condition and develop a heuristic algorithm to find out the near optimal results for a test problem.

**3 - Blockchain Adoption under Uncertainty of Regulation**

Reza Alizadeh, The University of Oklahoma, 815 Russell Circle, E.  
Brooks St, Norman, OK, 73071, United States, Leili Soltanisehat

Demand for decentralization of the organizational processes is getting strong throughout the world. The entity of the decentralization technology and the governmental regulations may differ among enterprises. We consider a decentralized IT system (Blockchain) inside an enterprise under uncertain governmental regulation and standards when there is a competitive tendency to adopt blockchain in the market.

**4 - Shared Decision Making (SDM) as a Fast Emerging Field in the Interface of OR / MS and Medicine: Its Past, Present, and Likely Future**

Juri Yanase, Complete Decisions, LLC, 10517 Springbrook Ave.,  
Baton Rouge, LA, 70810, United States, Evangelos Triantaphyllou,  
Zaina Qureshi

The rapid evolution of medicine has resulted in multiple treatment options for many chronic conditions. These treatments are associated with different risk-benefit profiles, and preferences by individual patients. SDM provides a unique platform for patients and clinicians to collaboratively determine the best treatment option for individual patients. We review SDM's history, the state-of-the-art and some challenges for the future.

**■ WD42**

North Bldg 227A

**Practice- Simulation and Optimization**

Contributed Session

Chair: Julien Vaes, University of Oxford, Kings Cross, London, NW1  
2DB, United Kingdom

**1 - Data Driven Optimization and Statistical Modeling to Improve Meter Reading for Utility Companies**

Debdatta Sinha Roy, Robert H. Smith School of Business,  
University of Maryland, 7699 Mowatt Lane, 3330 Van Munching  
Hall, College Park, MD, 20742, United States, Christof Defryn,  
Bruce L. Golden, Edward Wasil

Utility companies collect usage data from meters on a regular basis. Each meter has a signal transmitter that is automatically read by a receiver within a specified distance using radio-frequency identification (RFID) technology. In practice, there is uncertainty while reading meters from the planned routes of the vehicles. The RFID signals are discontinuous, and each meter differs with respect to the specified distance. These factors can lead to missed reads. We use data analytics, optimization, and Bayesian statistics to address the uncertainty. Simulation experiments using real data show that a hierarchical Bayesian model performs the best by designing improved routes for the vehicles.

**2 - UNIPOPT: Univariate Projection-based Optimization without Derivatives**

Ishan Bajaj, Texas A&M University, College Station, TX, 77840,  
United States, Faruque Hasan

We present a novel derivative-free framework UNIPOPT (UNivariate Projection-based OPTimization) based on projecting all the samples onto a univariate space defined by summation of the decision variables. We illustrate that a univariate function (defined as lower envelope) exists on this space such that its minima is the same as that of the original function. The UNIPOPT framework identifies the points on the lower envelope and uses these samples to optimize it. UNIPOPT finds solutions within 1% of the global minima for 10-30% more problems compared to other solvers when applied on 485 constrained black-box problems. We also show the convergence of UNIPOPT to first order critical point.

**3 - Design a Power Network for Charging Electronic Vehicles**

Ting Wu, Nanjing University, Department of Mathematics, No 22  
Hankou Road, Nanjing, 210093, China, Cheng Zhu, Yasmina Maizi

Electronic Vehicles contribute to a green environment in a smart city, they, however, raise a challenging problem for an existing power network to accommodate their charging facilities. This study aims to verify an upgraded power network via simulation models, providing managerial insights for adjusting existing power networks given a transportation network.

**4 - Optimal Trade Execution Strategy under Volume and Price Uncertainty**

Julien Vaes, University of Oxford, Andrew Wiles Building,  
Radcliffe Observatory Quarter, Woodstock Road, Oxford, OX2  
6GG, United Kingdom, Julien Vaes, The Alan Turing Institute,  
96 Euston Road, Kings Cross, London, NW1 2DB, United Kingdom

In the seminal paper on optimal execution of portfolio transactions, Almgren and Chriss define the optimal trading strategy to liquidate a fixed volume of a single security under price uncertainty. Yet sometimes, like in the power market, the volume to be traded can only be estimated and becomes more accurate when approaching a specified delivery time. We develop a model that accounts for volume uncertainty and show that a risk-averse trader has benefit in delaying trades. We demonstrate that the optimal strategy is a trade-off between early and late trades to balance risk associated to price and volume respectively.



## ■ WD43

North Bldg 227B

### Climate Impacts on the Electric Power Sector

Emerging Topic: Energy and Climate

Emerging Topic Session

Chair: Delavane Diaz, Electric Power Research Institute, Washington, DC, 20005, United States

Co-Chair: John Bistline, Electric Power Research Institute, CA, United States

#### 1 - Climate Change Vulnerabilities of New York State's Future Electric System

Delavane Diaz, Electric Power Research Institute, Washington, DC, 20005, United States

This paper estimates potential impacts of future climate conditions on the NY electricity system through 2050 using EPRI's US-REGEN model. Specifically, we evaluate future climate changes as characterized in the NY ClimAID assessment through the following climate impact pathways: temperature impacts on of thermal generation and transmission efficiency, water availability for hydro generation and cooling, and temperature impacts on electricity demand.

#### 2 - An Integrated Approach to Climate Impacts on Power Sector Using GCAM

Mohamad Hejazi, Research Scientist, Joint Global Change Research Institute, Pacific Northwest National Laboratory, College Park, MD, 20740, United States, Zarrar Khan, Gokul Iyer, Marshall Wise, Pralit Patel, Sonny Kim

Energy, water, and land systems are increasingly interconnected. In this study, we use the Global Change Assessment Model (GCAM), where interactions between population, economic growth, energy, land, and water resources interact simultaneously in a dynamically evolving system, to investigate the direct and indirect effects of climate impacts on the electric sector under different scenarios.

#### 3 - Does Water Scarcity Shift the Electricity Generation Mix toward Fossil Fuels? Empirical Evidence from the United States

Jonathan Eyer, USC, Casey Wichman

Using an econometric model of plant-level electricity generation between 2001 and 2012, we estimate the effect of water scarcity on the US electricity mix. We find that hydroelectric generation decreases substantially in response to drought, and the replacement fuel varies by region. We quantify the substantial social costs associated with the increased carbon emissions.

## ■ WD44

North Bldg 227C

### Joint Session ENRE/Practice Curated: Data Science in Energy Systems

Sponsored: Energy, Natural Res & the Environment/Electricity

Sponsored Session

Chair: Hoon Hwangbo, Texas A&M University, College Station, TX, United States

Co-Chair: Eunshin Byon, University of Michigan, Ann Arbor, MI, 48109, United States

#### 1 - Variance Reduction Method for Wind Turbine Extreme Load Estimation

Qiyun Pan, University of Michigan, Department of IOE, Ann Arbor, MI, 48109-2117, United States, Eunshin Byon, Henry Lam

This study develops a computationally efficient variance reduction method for wind turbine extreme load estimation with the stochastic simulation model. We propose an adaptive method that iteratively refines the input sampling density so that sampling efforts can be steered to focus on important input regions. We devise a parameter updating rule to make the sampling density parameter converge to the unknown target extreme load and prove the extreme load estimation uncertainty becomes smaller than that from crude Monte Carlo simulation.

#### 2 - Quantifying the Effect of Vortex Generator Installation on Wind Power Production

Hoon Hwangbo, Texas A&M University, College Station, TX, 77840, United States, Yu Ding

Vortex generator installation is known to improve wind power production, and how much to improve is a fundamental managerial question to be addressed. Quantifying the effect of the installation is, though, quite challenging due to the presence of multiple sources of variation causing difference in power output between pre- and post-installation periods. For more accurate quantification, we use a machine learning model to control for some environmental effects in power

output and consider the temporal change of wind power production between the two periods of installation, which shows quite consistent results.

#### 3 - Update on NREL Work in UQ for Loads Analysis

Katherine Dykes, NREL, Golden, CO, United States

This presentation will provide an update on NREL work using statistical methods applied to wind turbine extreme and fatigue loads analysis. Loads analysis is a cumbersome part of wind turbine design and analysis with significant uncertainty; advanced statistical methods can help improve the accuracy and computational efficiency of this process.

## ■ WD45

North Bldg 228A

### Electrical Markets

Contributed Session

Chair: G ray Kara, Norwegian University of Science and Technology, Høgskoleringen 1, Trondheim, 7491, Norway

#### 1 - Long- and Short-term Uncertainties in the Capacity Expansion Problem with Renewables and Electric Vehicles

Miguel Carrion, Universidad de Castilla-La Mancha, Campus Tecnológico Fabrica de Armas, Toledo, 45071, Spain, Ruth Dominguez, Rafael Zárate-Miñano

This paper solves a coordinated generation and storage expansion problem considering long- and short-term uncertainties. We assume that the power system operator is able to control the charging processes of those electric vehicles that are willing to get involved in the power system operation in exchange for a financial reimbursement. The day-ahead energy and reserve capacity markets are explicitly considered in this capacity expansion problem. The resulting stochastic mixed-integer linear problem is solved using Benders decomposition. The proposed formulation is tested on a realistic case study based on an actual isolated power system in Spain.

#### 2 - An Enhanced Argonne Least Cost Electricity Analysis Framework: Impact of High Penetration of Electrified Vehicles

Jonghwan Kwon, Argonne National Laboratory, Lemont, IL, United States, Zhi Zhou

This study investigates the impact of electrified vehicles with fast charging technology on electricity grid operations, market efficiency, and emission. An enhanced Argonne Least Cost Electricity Analysis Framework (ALEAF) will be used to analyze the impact of fast charging station deployment and status profile in Chicago urban region, which will be provided by a transportation system simulation tool (POLARIS). The modeling framework includes electric grid and market operation models, formulated into multi-stage mixed integer programming problems. This study will allow the industry to understand economic viability of infrastructure and energy implications of vehicle electrification.

#### 3 - The Value of Flexibility in Electricity Markets from Gas Turbine Upgrades: A Stochastic Mixed Integer Programming Approach

Sourabh Dalvi, Pennsylvania State University, Leonhard Building, University Park, PA, 16802, United States, Mort Webster

The expected increase in generation from renewables and the consequent increased variability in net load has led to calls for more flexible resources in the generation mix. One potential source of flexibility is from performance improvements to existing gas turbines, including higher maximum output, lower minimum output, faster ramping, and less time and lower cost for startups. We apply a stochastic multi-stage mixed integer linear program to model the power system of Public Service of New Mexico, and demonstrate the relative value of different upgrades to the system and to the unit owner.

#### 4 - Production Intermittence in Spot Electricity Markets

Arthur Thomas, PhD Student, IFP Energies Nouvelles, 4 avenue de Bois-Préau, Rueil-Malmaison, 92852, France University of Nantes, Chemin de la Censive du Tertre-Batiment Erdre, Nantes, 44322, France, Albert Banal-Estañol, Olivier Massol, Augusto Rupirez Micola

This paper analyses the influence of production intermittence on spot markets. We use both game theory and an adaptation of the Camerer and Ho (1999) behavioural model. Controlling for costs, we find that intermittent technologies yield lower prices when incumbents have individual market power, but are higher when they do not have it. This happens both when firms are risk-neutral and risk-averse, and also under different intermittence and ownership configurations. Replacing high-cost assets with low-cost ones results in higher prices than when they are left to co-exist. The findings have implications for, among others, wholesale electricity markets in which wind power is increasingly important.

### 5 - Modeling Demand-side Flexibility in Electricity Markets

G ray Kara, PhD Candidate, Norwegian University of Science and Technology, Trondheim, Norway, Asgeir Tomasgard, Hossein Farahmand

Increase in variable renewable energy sources, electrical vehicles, batteries etc. shaped load profiles and generation plans. The term flexibility is not new in supply-side power markets studies. However, the flexibility in demand-side gathered attraction in recent times by the support of developing technologies. In this study, our aim is the characterization of flexibility resources in energy markets along three classes: Time, spatial, and provision. We examine demand-side flexibility in stochastic optimization models by considering availability and geographical relevance from different flexibility providers.

## ■ WD46

North Bldg 228B

### Sustainable Electricity Systems

Sponsored: Energy, Natural Res & the Environment/Energy

Sponsored Session

Chair: Destenie Supreece Nock, Univ. of Mass-Amherst, Hadley, MA, 01035, United States

#### 1 - Scenario Grouping for Stochastic Unit Commitment

Amelia Musselman, Postdoctoral Researcher, Lawrence Livermore National Laboratory, Livermore, CA, 94551, United States, Kevin C. Ryan, Deepak Rajan, Jean-Paul Watson

In this research, we introduce an algorithm to intelligently group scenarios within a scenario decomposition algorithmic framework for solving stochastic programs. Two variations of the algorithm are implemented as fully general extensions to PySP's (Pyomo's stochastic programming library) implementation of the iterative progressive hedging algorithm for solving stochastic programs. In the first, scenario grouping is used as a pre-processing step to progressive hedging. In the second, scenarios are grouped in each iteration until the bounds given by grouping converge. The two algorithms are applied to solve increasingly difficult instances of stochastic unit commitment.

#### 2 - The Midcontinent Independent System Operator Renewable Integration Impact Assessment

Armando Figueroa, PhD, MISO

This presentation will show an overview of the Renewable Integration Impact Assessment study conducted at the Mid-Continent Independent System Operator. The study framework will be highlighted, including preliminary results related to the resource adequacy, energy adequacy, and operating reliability modules.

#### 3 - Sustainable Electric Generation Portfolios: A Multi-criteria Decision Analysis Framework Applied to the New England Power System

Destenie Supreece Nock, Univ. of Mass-Amherst, Hadley, MA, 01035, United States, Erin Baker

We evaluate the sustainability of electric generation portfolios, using a multi-criteria decision analysis approach applied to the New England power system. We evaluate sustainability of generation portfolios using a set of seven sustainability criteria. Here generation portfolios with varying levels of offshore wind, natural gas, hydro, and nuclear, are considered under various preference scenarios. We find that when the most weight on air pollution and climate change, adding nuclear capacity is a dominant choice. If avoiding nuclear and conserving water is most important, then retiring oil and nuclear while adding high levels of offshore wind rises to the top.

## ■ WD47

North Bldg 229A

### Practice- Sustainable Operations & Development

Contributed Session

Chair: Anita Lee-Post, University of Kentucky, Department of Marketing and Supply Chain, 455f Business & Economics Bldg, Lexington, KY, 40506, United States

#### 1 - The Value of Quality Grading in Remanufacturing under Quality Level Uncertainty

Meltem Denizel, Iowa State University, 2340 Gerdin Business Building, 2167 Union Dr., Ames, IA, 50011-2027, United States, Ihsan Yanikoglu

In remanufacturing, variability in quality levels of cores has an impact on both the process cost and time. While previous research suggest that quality grading adds value, there are also concerns about how reliably the grades can be identified. We develop a robust optimization model for remanufacturing planning. Both the unit cost and time of remanufacturing are uncertain parameters that are assumed to reside in two uncertainty sets; box or ellipsoidal. We analyze

un capacitated and capacitated cases and based on extensive numerical analysis, conclude that while there is still value in grading on average, it becomes significantly smaller than the case when uncertainty is not accounted for.

#### 2 - Firm Performance through Corporate Social Responsibility Leveraging the Supply Chain

Feng Cheng, PhD Candidate, Arizona State University, Tempe, AZ, United States

This study examines the effect of supply-chain CSR adoption - i.e. adoption of Corporate Social Responsibility in the value chain (from supply base to customer base) - on the focal firm's financial performance. Our results show that supply-chain CSR does not necessarily lead to superior firm performance. We uncover pathways that can benefit a firm from the adoption of supply-chain CSR; namely, (1) innovation driven from both focal firm CSR and supply-chain CSR and (2) employee performance. The results suggest that a firm benefits from supply-chain CSR only if the adoption inspires innovation and high employee productivity. Such positive effect becomes larger in less eco-friendly industries.

#### 3 - Optimal Fleet Size and the Efficiency-effectiveness-equity Trade-offs in Humanitarian Procurement Policies

Laura Turrini, European Business School, Oestrich Winkel, Germany

We focus on fleet management and empirically estimate the real needs of a decentralized humanitarian organization that operates both relief and development operations. We study the optimal allocation of vehicle procurement, based on a set of constraints, in order to satisfy organizational needs as efficiently, effectively and equitably as possible.

#### 4 - Sustainable Consumption Behavior

Anita Lee-Post, University of Kentucky, Department of Marketing and Supply Chain, 435Q Business & Economics Bldg, Lexington, KY, 40506, United States, Chon-Huat Goh

The purpose of this research is to further our understanding on sustainable consumption behavior. An empirical study is sought to investigate the pathway linking attitude, social influence, and sustainable consumption behavior using a survey methodology. Operational and marketing implications of findings from this study will be presented.

## ■ WD48

North Bldg 229B

### Uncertainty-Driven Power Systems Planning and Operation Supporting Resilience

Sponsored: Energy, Natural Res & the Environment/Energy

Sponsored Session

Chair: Dehghanian Payman, George Washington University, 800 22nd St. NW, Science and Engineering Hall (SEH) 6630, Washington, DC, 20052, United States

#### 1 - Big Data Analytics in Large Scale Power Grid Economic Planning

Yingzhong Gu, PhD, GE Energy Consulting, Schenectady, NY, 12345, United States

Power system economic planning is a core part of a comprehensive power system planning process, which not only considers the needs for reliability, public policy and resource adequacy but also it well addresses the long-term needs for a more economical and efficient power grid operation. The power system economic planning, using production simulation tool, evaluate the current and future state of bulk power grid and the economic impact of various projects to reduce the overall operation cost in the long run. GE Multi-Area Production Simulation (MAPS) is widely adopted to conduct various power system economic planning studies including renewable integration studies, market efficiency evaluation studies, transmission planning studies, and congestion assessment studies, etc. One of the major challenge of power system economic planning is to conduct long-term (i.e. 20-30 years) production simulation for large scale power systems. The big data analytics technology is a key to facilitate the state-of-the-art power system economic planning. This seminar introduces some major efforts GE is taking toward this new era.

#### 2 - Resilience of Power Systems to Black Sky Hazards – Methods, Metrics and Thoughts

Mathaios Panteli, The University of Manchester, Manchester, United Kingdom

Recent extreme events, such as severe storms and earthquakes, have placed resilience in the spotlight for power system operators and regulators worldwide. Hence, there is a growing concern over the critical need to address and boost resilience to such disastrous events, which are referred to as Black Sky hazards. This talk will share experiences gained from relevant research projects in United Kingdom in the area of resilient power systems planning and operation. Amongst other, insights will be provided on conceptual frameworks, methods and metrics suitable for resilience analysis and further thoughts will be provided towards designing future resilient power systems.

### 3 - Online Resilience Support for Grid Cyber-Physical Situational Awareness

Katherine Davis, PhD, Texas A&M University, College Station, TX, 77843, United States

High-quality situational awareness enables rational tactical and strategic decision support. This talk describes work on bringing together expertise and methodologies for cyber-physical grid resilience that each make significant progress toward this goal. We explore synergies of these efforts and describe how they can lead to enhanced situational awareness across domains, where the focus is on the decision-making process in real-time cyber-physical systems through the steps of observe-orient-decide-act. The talk will investigate the design of the decision-making process in the CyPSA framework with a focus on decisions that promote grid cyber-physical resilience.

### 4 - Networked Community Microgrids Planning for Enhancing the Resilience in Power Grids

Masoud Barati, PhD, University of Pittsburgh, Pittsburgh, PA, 15260, United States

We proposed a resilient planning problem of networked microgrids with DERs. We integrate the investment problem and two sets of operating problems associated with the grid-connected and islanding modes of microgrids into a two-stage stochastic model to capture randomness nature of hazard events and long-term load growth, as well as the islanding risk caused by external disturbances with a joint-chance constraint to prevent the risks. A SOCP formulation is presented to incorporate AC-OPF in short-term operation. Numerical results on distribution systems prove the effectiveness of the model.

### 5 - AC Optimal Power Flow with Robust Feasibility Guarantees

Line Roald, Los Alamos National Laboratory, Los Alamos, NM, 87544, United States

With increasing uncertainty from renewable energy, optimization problems that explicitly consider uncertainty are increasingly important to the operation of electric power systems. We discuss our work towards a robust AC Optimal Power Flow (OPF) algorithm. Ensuring robust feasibility requires 1) ensuring solvability of the power flow equations and 2) guaranteeing feasibility of the engineering constraints for all uncertainty realizations. We use convex relaxations to bound the impact of uncertainty, leading to conservative results. The solution is obtained using an alternating solution algorithm, and the approach is illustrated via analyses of two small test cases.

## ■ WD49

North Bldg 230

### Energy Policy and Planning IV

Contributed Session

Chair: Mark Rodgers, Rutgers Business School, South Orange, NJ, 07079-1466, United States

#### 1 - Electric Business Modeling for Optimal Design of Isolated Power Systems

Aito Yasuda, Osaka University, Osaka, Japan, Hiroshi Morita

In recent years, long-term cut off of power supply is anticipated by large-scale disasters. An isolated electric system is an electric power model in which power demand equipment is operated by a power generation and a storage battery without using power supply from the grid. We derive an optimal design of the capacity of solar panel and storage battery of isolated electric system to keep the quality of life in the event of disaster. We also investigate an operation model for multiple isolated electric systems connected by a network.

#### 2 - Risky Capacity Equilibrium Models for Risk Averse Investment Equilibria with Incomplete Markets

Daniel Ralph, University of Cambridge, Judge Business School, Trumpington Street, Cambridge, CB2 1AG, United Kingdom, Gauthier de Maere, Andreas Ehrnemann, Yves Smeers

Risky Capacity Equilibrium Problems" incorporate (i) risk averse investment in power plants, (ii) financial trading to hedge those investments, and (iii) strategic production in a stochastic spot market. These models concatenate short-term electricity market (perfect competition or Cournot) with long-term investments (risk neutral or risk averse behaviour in different risk trading settings). We focus on incomplete financial markets, when not all risks can be traded, using results from "Risky Design Equilibrium Problems" and standard Nash game techniques to show existence of equilibria. Numerical results show the impact of incompleteness on equilibrium capacity and spot prices.

#### 3 - Solving the Bi-level Problem of a Closed Optimization of Price Zone Configurations in Europe Using a Genetic Algorithm

Tim Felling, Research Assistant, University Duisburg-Essen, Berliner Platz 6-8, Essen, 45127, Germany

In Europe, the reconfiguration of price zones (PZ) is under discussion in both politics and academia. Yet, current research focusses either on approximations using algorithms that cluster nodes to PZ for large-scale grids or on closed optimizations on smaller scale. We contribute to the discussion by formulating the problem of optimal PZs as a closed bi-level problem that considers day-ahead and

redispatch markets. The PZ configuration is reflected by a node-to-zone assignment using binary variables. For its solution, we apply a suited genetic algorithm on a large-scale grid of Western Europe.

#### 4 - Market Model for Electric Vehicle Battery Aggregator

Ivan Pavic, University of Zagreb, Unska 3, Zagreb, 10000, Croatia, Hrvoje Pandzic, Tomislav Capuder

There are more than three million EVs on the roads which accounts to more than 70 GWh of storage capacity. Controlled charging can become an interesting option to provide flexibility to power system. EV aggregator is an entity which groups EV chargers and submit their aggregated power on electricity or balancing markets. Such entity can use EVs' flexibility only when they connected to their dedicated chargers. We propose a new entity called electric vehicle battery aggregator (EVBA) which follows EV as part of internet of things concept and charge them optimally for end-users throughout longer periods. EVBA concept can be part of EV routing and infotainment application responsible for power supply.

#### 5 - System Implications of Continuous-time Dispatching in Electricity Markets

Mark Rodgers, Assistant Professor, Rutgers Business School, 1 Washington Park, Newark, NJ, 07102, United States, Wenbo (Selina) Cai, Xiaowei Xu, Frank A. Felder

In centralized electricity markets, supply and demand are balanced on discrete time intervals, but demand volatility occurs on a more granular level. Additionally, markets with large renewable shares experience higher levels of supply volatility due to intermittent weather patterns. While batteries partially reduce supply volatility, there is a need for a real-time, load-balancing mechanism. In this research, we study the supply and demand volatility in the context of a continuous time, load-balancing framework. Additionally, we assess the resulting effects of this framework, along with the impact of battery storage investments, on wholesale electricity prices.

## ■ WD50

North Bldg 231A

### Strategic Planning and Applications I

Contributed Session

Chair: Achal Bassamboo, Northwestern University, 2001 Sheridan Road, Evanston, IL, 60208, United States

#### 1 - In Need of Aid: Funding Uncertainty and Diversification in Humanitarian Operations

Gloria Urrea, Indiana University, 3631 East Park Lane, Bloomington, IN, 47408, United States, Sebastian Villa, Eric Quintane

Research on resource dependence focuses on the strategies dependent organizations follow to access resources in order to survive. In the humanitarian context, humanitarian organizations (HOs) depend on resources from donors and diminish their dependence by accessing multiple sources of funding. We argue that while finding additional sources of funding reduces current uncertainty and enables survival, it decreases the organization's capacity to diversify (i.e. to venture into new service sectors and geographical regions) because it does not reduce future uncertainty. We use information from over 30,000 donations provided by 222 donors to 845 HOs during 1999-2016 to test our hypotheses.

#### 2 - Tracking Passengers' Routes in Urban Railway Networks Using Integer Programming

Daichi Tahara, Osaka University, Osaka, Japan, Shunji Umetani, Hiroshi Morita

The analysis of a population's mobility patterns has become much important in recent years. However, it still remains much difficult due to incompleteness and unreliability of public traffic survey data. We now propose an integer programming approach to track individual passengers' routes in urban railway networks from a given spatiotemporal distribution of anonymous passengers. We evaluated the proposed method numerically based on Japanese public traffic survey data, and observed that it tracked actual passengers' routes with high accuracy.

#### 3 - Launching Next Generation Products in a Competitive Market

Rob A. Zuidwijk, Professor Ports in Global Networks, Erasmus University Rotterdam, RSM Erasmus University, P.O. Box 1738, Rotterdam, 3000 DR, Netherlands, Xishu Li, Rene de Koster, Suresh P. Sethi

We report on our research on how two competing firms launch a next-generation product (NGP) in terms of timing and capacity allocation between the NGP and an existing basic product. Our research focuses on the impact of a two-dimensional competition: the internal competition between the two products and the external competition between the two firms. We demonstrate that demand uncertainty and competition between the firms should be taken into account jointly while deciding on timing and capacity allocation.



#### 4 - Data-driven Decision Making in Last Mile Delivery Problems

Sami Serkan Zarik, PhD Candidate, Eindhoven University of Technology, School of Industrial Engineering (Pav. F08), P.O. Box 513, Eindhoven, 5600 MB, Netherlands, Lucas Petrus Veelenturf, Tom Van Woensel, Gilbert Laporte

The recent increase in online orders leads to logistical challenges such as low hit rates (number of successful deliveries) and unattended deliveries. In this paper, we consider exact and heuristic approaches in order to solve last mile delivery problems in which customers' attendance probability data is considered for each of the time buckets in the planning horizon. We aim to improve the hit rate by considering routing and scheduling decisions. We develop an efficient heuristic approach by iteratively solving routing and scheduling problems. Numerical results will be presented.

#### 5 - Partnership Uncertainty and Jugaad

Achal Bassamboo, Northwestern University, 2001 Sheridan Road, Evanston, IL, 60208, United States, Sanket Patil, Prateek Raj

The paper models how partnership uncertainty influences the level of investment in new projects. When businesses can delay their decisions to invest and instead search for an outside option (do Jugaad) uncertainty in commitment can emerge. We find that Jugaad can lead to a tragedy of commons, where it is individually rational to expand the option set, but such a large option set reduces commitment to new projects and hampers overall level of investment.

### ■ WD52

North Bldg 231C

#### Practice- Transportation Freight II

Contributed Session

Chair: Allan Larsen, Technical University of Denmark, DTU Management Engineering, Building 424, DTU, Lyngby, DK-2800, Denmark

##### 1 - Truck Appointment Systems Considering Impact to Drayage Truck Tours

Mohammad Torkjazi, University of South Carolina, Columbia, SC, 29205, United States, Nathan Huynh, Samaneh Shiri

This study proposes a novel approach for designing a Truck Appointment System (TAS) intended to serve both the marine container terminal operator and drayage operators. The aim of the proposed TAS is to minimize the impact to both terminal and drayage operations.

##### 2 - Design and Operation of China Railway Express under Market Competition

Yingzi Peng, Tsinghua University, Beijing, 100084, China, Lefei Li

As an important symbol of "The Belt and Road transportation interconnection, China Railway Express has obtained a great increase in the number of commodity freight. Most mathematical models of intermodal network design have been developed as stakeholder of an intermodal operator. In this research, we develop a network design and operation model in order to help China Railway Express, as a carrier, to solve for better freight routes and schedules considering competition with other carriers. The model is formulated as a bilevel nonlinear integer program, which is difficult to solve.

##### 3 - Design of a Relay Network in Long-haul Transportation

Amin Ziaefar, Southern Methodist University, Dallas, TX, 75205, United States, Halit Uster

We present a new model to strategically design a relay network for long-haul transportation by considering alternative routings. We devise a Benders decomposition based solution algorithm that is enhanced by strengthened benders cuts, heuristics, and surrogate constraints to solve it efficiently. We present the computational results to demonstrate the efficiency of our algorithm on large-scale instances.

##### 4 - Freight Demand Modeling in Bangladesh: A World Bank Project

Abdelrahman Ismael, Rensselaer Polytechnic Institute, Troy, NY, 12180, United States, Jose Holguin-Veras, Lokesh Kumar Kalahasthi, Wilfredo Yushimito

This presentation explains the freight modeling performed as a part of a project funded by the World Bank group. Freight generation, freight trip generation were modelled at district level in Bangladesh, using the survey conducted by the team. Freight Origin-Destination Synthesis, a process of obtaining the loaded and empty flows between the districts was performed, using the confidential Census datasets, road network, link travel time estimated using the GPS data, and the traffic count data for year 2013. Imports and export traffic flows were modeled using the Customs data. A doubly constrained gravity model is used for trip distribution, and Noortman and van E's model is used for empty trips.

##### 5 - Using Electric Vehicles for Commercial Urban Transports

Allan Larsen, Professor, Technical University of Denmark, DTU Management Engineering, Building 424, DTU, Lyngby, DK-2800, Denmark, Dario Pacino, Michael Bruhn Barfod, Jonas Mark Christensen, Satya Sarvani Malladi

Electric vehicles (EVs) are facing a rapid development enabling such vehicles to be used in commercial transport. The EU project, EUFAL (Electric Urban Freight and Logistics), sets out to examine the potentials of using EVs in city logistics. This presentation will provide an overview of the planning and management problems met when implementing EVs in urban freight transport. Two real-life optimization problems dealing with routing EVs for collection of blood samples from private physicians and the fleet management of electric service vehicles visiting construction sites will be introduced.

### ■ WD53

North Bldg 232A

#### Behavioral Operations II

Contributed Session

Chair: Hsuanwei Chen, San Jose State University, One Washington Square, San Jose, CA, 95192, United States

##### 1 - Decision Making under Uncertain Demand and Uncertain Supply

Somak Paul, The Ohio State University, Columbus, OH, 43202, United States, Elliot Bendoly, Nathan C. Craig

There has been little empirical effort to distinguish the implications of demand and supply uncertainty separately on inventory decisions when both are present. In this study we design a controlled laboratory experiment to investigate the impact of demand and supply variability, as well as feedback frequency and experience on the optimality of the inventory decisions made. While we find the impact of demand uncertainty to be in line with standard assumptions, the impact of supply uncertainty appears counter-intuitive. We find that supply variability has a dampening effect on order deviation from the optimal and imposes limits on the extent to which experience benefits optimal ordering choice.

##### 2 - Ordering Behavior in the Beer Game: An Agent-based Simulation Approach

Jaime Andr s Castañeda, Universidad del Rosario, CL 12 C. 6 25, School of Management, Bogotá, 111711, Colombia, John Vargas, Daniel Rodríguez, David Anzola, Nelson Gómez

This study analyzes the bullwhip effect through an agent-based simulation approach. We simulate the Beer Game, where an agent simulates each echelon. The agents place their orders according to Stermann (1989)'s ordering rule. We systematically manipulate the behavioral parameters of the rule across the agents and use clustering techniques to determine what behavioral configurations are beneficial for the supply chain.

##### 3 - How Market Power Impacts Investment in Supply Chain Theory and Experiment

Jingjie Su, University of Texas at Arlington, Box 19437, Arlington, TX, 76019, United States, Kay-Yut Chen

Consider a supply chain network with two players, OEM and CM. They have relationships both as downstream supplier and competitor in the market. Now, when OEM has an option to invest in CM, based on different investment cost and market power, the theory predicts the different decision. Behavior experiment differs.

##### 4 - A Novel Approach to Propensity Score Matching Incohort Construction Forbehavioral Nudging in Health Care

Ryan Croke, Data Scientist, NextHealth Technologies, Denver, CO, 80202, United States

A novel approach to cohort construction in a health care application is presented. Propensity score matching is used as a baseline to construct a control group to a given trial set. The experiment is aimed at illiciting positive health decisions by insured consumers and with large and rich datasets. In an effort to ameliorate the concerns of various researchers a hybrid method is used that optimizes over the member attributes as well as the propensity score.

##### 5 - A Semantic Analysis of Super Bowl Word of Mouth on Tourism Social Media

Hsuanwei Chen, Assistant Professor, San Jose State University, One Washington Square, San Jose, CA, 95192, United States, Yinghua Huang

This study investigates how tourism social media word-of-mouth changes before and after a mega event. Using Super Bowl 2016-2018 as an example, semantic analysis is applied to explore the popular topics among tourists' interactions on Twitter. Specifically, two questions will be answered: 1) what do tourists discuss about Super Bowl and its host destination on Twitter? and 2) how do tourists' topics of interest evolve as the event progresses? The findings will help the destination event planners to better understand tourists' opinions and monitor the issues emerged from the trajectory of the event.

## ■ WD55

North Bldg 232C

### Practice- Technology and Project Management

Contributed Session

Chair: Christian Ruf, Technical University Munich, Arcisstr. 21, München, D-80333, Germany

#### 1 - Motivating Employees' Information Security Compliance: Leadership Style or Protection Motivation?

Jiawen Zhu, Xi'an Jiaotong University, Xi'an, China  
Jiawen Zhu, City University of Hong Kong, Hong Kong, China,  
Gengzhong Feng, Kwok Leung Tsui

This study investigates the moderation effect of Paternalistic Leadership on the relationship between Protection Motivation Theory and employees' Information Security Compliance behavior. Using questionnaire data from 760 employees, we found that, Paternalistic Leadership dimensions, Authoritarianism, Benevolence, Morality, dampen the weight of most protection motivation elements to employees' compliance. This suggests that when certain leadership style is salient, employees' protection motivation perceptions, such as threat severity, self-efficacy and maladaptive reward perception, may have no significant influence on employees' information security compliance.

#### 2 - Asymmetric Information Sharing in Information System Security

Yueran Zhuo, University of Massachusetts Amherst, 121 Presidents Drive, Amherst, MA, 01003, United States, Senay Solak

In information security practice, the asymmetry in information sharing levels might hurt the information sharing firms' incentives. A possible solution to the problem is to impose charges on the shared information and treat it as a commodity. In this study we try to answer the questions: What fair price should a firm pay when also sharing a certain level of information? How would the price of information vary as more firms join an information sharing alliance? We develop analytical expressions to identify the pricing of information in an information sharing community with multiple firms and explore the overall benefits to the information sharing community due the implementation of pricing strategies.

#### 3 - Introducing a Predator-prey System with Michaelis-menten Type of Prey and Predator Harvesting Considering Diffusion Terms and Inconstant Carrying Capacity for the Prey

Aram Bahrini, University of Virginia, Thornton Hall,  
P.O. Box 400259, Charlottesville, VA, 22904-4259, United States  
University of British Columbia, 1984 Mathematics Road, UBC,  
Vancouver, BC, V6T1Z2, Canada, Behnam Malmir,  
Mohammad Najjartabar Bisheh

In this paper, we made a modification on the Hu and Cao (2017) model in which in our model the effect of harvesting for the prey is non-zero and considered as a Holling II functional response predator-prey system. In addition, since by changing the reproduction rate, the carrying capacity may change as well, the scenario in which the carrying capacity is considered as unfixed and a function of reproduction rate for the prey is taken into consideration. Additionally, a diffusion term is added to make the model more realistic especially in fishery application. Results show that the model analyzed in this paper can cause more realistic behaviors compared with other presented systems.

#### 4 - Long-term Capacity Planning of a Workforce with Hierarchical Skills and Random Resignations

Christian Ruf, TU München, Arcisstr. 33, Munich, 80333, Germany, Jonathan F. Bard, Rainer Kolisch

We address a multistage capacity planning problem for a hierarchically skilled workforce. Recruits are hired and trained over multiple periods to perform jobs that require ever greater skills. The training comprises a combination of off-the-job and on-the-job elements. Random resignations result in labor shortfalls that jeopardize continuous operations. The problem is modeled as a Markov decision process for which a parameterized decision rule is proposed. To determine good parameter values, we present a very large-scale neighborhood search. Experimental results on real-world industry data is presented.

## ■ WD56

West Bldg 101A

### Data-driven Modeling in Healthcare

Sponsored: Health Applications

Sponsored Session

Chair: Taewoo Lee, University of Houston, Houston, TX, 77204-4008, United States

#### 1 - A Two-stage Stochastic Model for the Operating Room Scheduling Problem with Chance Constraints

Amirhossein Najjarbashi, University of Houston, E206 Engineering Bldg 2, 4722 Calhoun Rd, Houston, TX, 77204, United States,  
Gino J. Lim

High variability of surgery durations is a major challenge towards creating practical OR schedules. To address this issue, we proposed a two-stage stochastic model with chance constraints. The first stage makes decisions on OR openings and case assignments to minimize fixed costs. The second stage aims to minimize the expected penalty costs after observing the surgery durations. Chance constraints control the risk of having OR overtimes. A decomposition-based method is developed based on the structure of the model. Coefficient strengthening and bounding are performed to accelerate the solution process. Numerical results show that our algorithm can handle large instances in a timely manner.

#### 2 - Online Scheduling for Outpatients

Kimia Ghobadi, MIT, 100 Main Street, E62-459, Cambridge, MA, 02142, United States, Retsef Levi, Michael Hu

In this talk, we demonstrate the use of real-time algorithms to improve patient care. We discuss resource utilization in infusion clinics. Many outpatient clinics, including infusion clinics, struggle to meet their demand due to crippling congestion in peak hours. At the same time, these clinics are often underutilized at non-peak hours. This underutilization is induced primarily by inappropriate scheduling practices. Therefore, we introduce a new scheduling model and employ real-time algorithms to improve efficiency by allowing the clinics to treat more patients with fewer resources. We show 30% empirical improvement and theoretical worst-case bounds on the performance of the algorithm.

#### 3 - Inferring Objective Functions from Inconsistent Data in Healthcare and Energy Applications

Taewoo Lee, University of Houston, E209 Engineering Bldg 2, 4722 Calhoun Rd, Houston, TX, 77204-4008, United States, Zahed Shahmoradi

Given often inconsistent observations as input data, we develop a new inverse optimization model that determines a set of objective functions of a linear program that render the most relevant subset of the observations near-optimal. We analyze the feasibility and optimality of the nonconvex inverse model and propose an algorithm that finds all inverse-feasible objective functions. Our approach addresses the infeasibility and instability issues of the previous inverse models. We demonstrate the model in the context of multi-objective diet recommendation and electricity demand forecasting.

#### 4 - Data-driven Objective Selection in Multi-objective Optimization

Temitayo Ajayi, Rice University, Houston, TX, 77025, United States, Taewoo Lee, Andrew J. Schaefer

A challenge in radiation therapy treatment planning is selecting which clinical objectives to use in the optimization. We propose an inverse optimization method with a cardinality constraint to infer the most important objectives from historical treatment plans. We use a greedy algorithm to select objectives and provide theory, a generalization of a result by Nemhauser (1978), to support our results. We compare the proposed method to the cardinality-constrained inverse problem and show that our method efficiently finds a small number of objectives that generates clinically acceptable treatment plans.

## ■ WD61

West Bldg 102C

### Practice – Supply Chain Competition, Practice and Risk Analysis

Contributed Session

Chair: Jian Li, Northeastern Illinois University, 5500 N. St Louis Avenue, Chicago, IL, 60625, United States

#### 1 - Supplier Development and Learning Spillover in a Triadic Supply Chain under Competition

Abhishek Srivastava, Doctoral Student, Indian Institute of Management Kozhikode, IIMK PO Kunnammangalam, Kozhikode, 673570, India, Arqum Mateen

We model a triadic supply chain in which two competing asymmetric buyers source from common supplier, invest in supplier development to improve profits. Buyers may benefit from each other's investment equally (uniform spillover; US) or unequally (differential spillover; DS). The supplier offers a uniform wholesale price (UWP) and buyer-specific wholesale price (BWSP). Our results indicate that optimal wholesale price increases with market share, intensity of competition, spillover effect. UWP under US works against the larger buyer, who consequently prefers a DS structure. We establish that both the buyers prefer investment under DS structure for higher values of competition and spillover.

#### 2 - A Study on Logistics Companies' Financial and Supply Chain Performance

Hossein Najmi, University of North Texas, 1307 W. Highland Street, Denton, TX, 76201, United States, Seock Hong

Financial performance indicators (FPIs) are long used to find supply chain excellence. But examining FPIs specific to a sector is understudied. To address this gap, we applied discriminant analysis, logistic regression, and MANOVA to analyze 103 logistics companies. We found the FPIs that measure the performance of logistics companies supply chain and differences among industries.

### 3 - Rush Purchasing for Hoarding during Natural Hazards – An Empirical Study in Agricultural Products Supply Chain

Hsintsz Kuo, National Taiwan University, New Taipei, 24943, Taiwan, Jiuh-Biing Sheu

Disruption management is the important part in the recovery process. This paper proposes a research model to investigate the causal relationships among internal influence and external influence, rush purchasing behavior and its antecedents after huge natural hazards. We argue that the emotional contagions can moderate the relationship among rush purchasing behavior and psychological response after a huge natural hazard.

### 4 - A Baseline Approach to Supply Chain Risk Assessment

João Dias da Silva, PhD Researcher, University of Porto, Porto, 4149-002, Portugal, Alcib ades Guedes

Over the past decades, global manufacturing and logistics networks have attained unprecedented levels of complexity, with supply chains becoming ever more prone to operational disruptions of unforeseen causes and consequences. This research project takes a fresh look at fundamental supply chain risk definitions and determinants, and proposes a new generic, coherent, repeatable and primarily intrinsic methodology to measure and rate the propensity for operational disruptions in supply chain systems. The rationale of the construct, some implementation examples, the relevance for theory and practice, as well as some anticipated limitations and potential improvements are discussed.

### 6 - Commodity Farming in Developing Countries with an Application to the Cotton Supply Chain in Mozambique

Jian Li, Northeastern Illinois University, 5500 N. St Louis Avenue, Chicago, IL, 60625, United States, Maqbool Dada, Panos Kouvelis

We develop a model of cotton supply chains in which two farmers, who are supported by two ginners, make two types of fundamental decisions under yield uncertainty: how much land to allocate to cotton production before the start of the growing season, and, the pricing rules followed by ginners that purchase the cotton harvest. The focus of the study is on characterizing the optimal decisions and the impact of a government-specified minimum price.

## ■ WD62

West Bldg 103A

### Joint Session DM/Practice Curated: Data Science in Transportation

Sponsored: Data Mining

Sponsored Session

#### 1 - Studying the Efficiency Limit of Ride Sharing

Mustafa Lokhandwala, PhD Candidate, Purdue University, West Lafayette, IN, 47906, United States, Hua Cai

Dynamic ride sharing offers passengers a facility to share a ride with others with the flexibility of choosing their own pick up and drop off locations while increasing the occupancy of vehicles up to a certain limit. We study this efficiency limit of ride sharing in autonomous electric vehicles using an agent-based model. Preliminary results have indicated that during peak hours, about 30% of the vehicles are available to accept new shares, but an approximately equal number of vehicles do not accept new shares. The most common reason (about 80%) that a taxi does not search for new shares has been found to be the tolerance limit of the rider to deviate from his route.

#### 2 - Dynamic Origin Destination Estimation Based on Time Delay Correlation Among Zonal Location-based Social Network Check-in Data

Jing Jin, Assistant Professor, Rutgers, The State University of New Jersey, CORE 613, 96 Frelinghuysen Rd., Piscataway, NJ, 08854, United States, Wangsu Hu

Location-based Social Network (LBSN) services allow users to confirm their current locations by “check-in with places of interests. Through analyzing the check-in arrival sequences, LBSN data can identify and quantify the spatial-temporal correlation of travel demand between pairwise zones to generate the dynamic Origin-Destination (OD) flow matrix. Empirical insights can be obtained by analyzing the predicted dynamic OD flow patterns for different land use types, day-of-week, and time-of-day periods.

## ■ WD63

West Bldg 103B

### Data Science for Health, Environment, and Energy

Sponsored: Data Mining

Sponsored Session

Chair: Yasin Unlu, LLamasoft Inc, Ann Arbor, MI, 48105, United States

#### 1 - Algorithms for the Upper Bound Mean Waiting Time in the Single-server Queue

Yan Chen, Columbia University, New York, NY, 10027, United States, Ward Whitt

Effective algorithms are developed to compute the tight upper bound of the mean steady-state waiting time in the GI/GI/1 queue given the first two moments of the interarrival-time and service-time distributions. A key step is to exploit the Marshall (1968) representation of the mean waiting time in terms of the idle-time distribution, which is insensitive to the rare event of the large service time. The algorithms are aided by reductions of these special queues to D/GI/1 and GI/D/1 models. One numerical algorithm exploits a negative binomial recursive formula, while another exploits a discrete-time Markov chain recursion. The computational efficiency for different methods is compared.

#### 2 - Baum Welch Method with Limiting Distribution Constraints

Daniel Waymouth Steeneck, Air Force Institute of Technology, Wright-Patterson AFB, OH, United States, Fredrik Eng Larsson

Training hidden Markov models (HMMs) is traditionally done using the Baum-Welch algorithm. However, in many cases, limiting distribution information is known about the hidden states via infrequent and expensive tests. Exploiting this information, we show how to modify the Baum-Welch algorithm to obtain a more accurate estimate for an HMM's transition matrix.

#### 3 - Robust Estimation of Controlled Hawkes Process

Michael Mark, PhD Candidate, EPFL, Route Cantonale, Lausanne, 1015, Switzerland, Thomas A. Weber

The identification of Hawkes-like processes can pose significant challenges. This applies even in a linear setting, as in an established model for the repayment arrivals of delinquent credit-card accounts where a bank controls the payment-arrival intensity using suitable account-treatment actions. Despite substantial amounts of data, standard estimation methods show significant bias or entirely fail to converge. To overcome these issues, we propose an alternative method based on expectation-maximization algorithm, that exploits the natural internal branching-structure of the process, thus providing additional information to the estimator.

#### 4 - Unsupervised Modeling and its Effectiveness for Fault Detection in Lacking Labeled Data

Hyunseop Park, PhD Candidate, Pohang University of Science and Technology, 77 Cheongam-Ro, Pohang, 37673, Korea, Republic of, Junhyuk Choi, Youngho Cho, Hyunbo Cho, JaeHyuk Kim

Fault detection in advance can reduce production losses due to equipment failure and unplanned stoppage. However, development of a supervised prediction model to detect faults is hindered by a lack of labeled data. Here, we present several unsupervised modeling methods for fault detection in cases that lack labeled data. The accuracy and computational time of the proposed modeling methods will be detailed and illustrated for various application conditions. Experimental results show that the unsupervised modeling methods yield significant accuracy when application conditions are considered.

#### 5 - Product Stage Analysis with Growth Curve Models

Yasin Unlu, Senior Operations Research Scientist, LLamasoft Inc, McKinley Towne Center, Ann Arbor, MI, 48104, United States

A typical product usually goes through different stages during its existence in the market; namely, launch (born), growth, maturity, decline and obsolescence. The duration of each stage is often of interest for making short or longer managerial decisions in an organization. We use s-shape growth models to predict the duration of each stage; namely, Logistics, Modified Logistic, Richards, Gompertz, Bass and Monomolecular as well as a tournament of these 6 models to provide the best modeling option. In order to improve the accuracy of predictions, we present different strategies for the parameter estimations of these models.



## ■ WD64

West Bldg 104A

**Joint Session DM/Practice Curated:  
Data Science for Text Analysis**

Sponsored: Data Mining

Sponsored Session

Chair: Babak Zafari, Babson College, Babson Hall 218C, Babson Park, MA, 02457, United States

**1 - Text Mining Analysis of Business Data Analytics and Data Science Jobs Requirements**

Zinovy Radovitsky, Professor, California State University-East Bay, 25800 Carlos Bee Boulevard, Hayward, CA, 94506, United States, Vishwanath Hegde, Anuja Acharya, Uma Uma

We identify and compare knowledge and skills for business data analytics (BDA) and data science (DS) professions. We collected primary BDA and DS job posting data from online job-related websites, developed document data matrix, and applied text mining analysis including singular vector decomposition, VARIMAX rotation, and latent class analysis. Based on this text mining analysis, we identified main similarities of and important differences between the BDA and DS job requirements. These results provide vital insights for designing curriculum and training in the evolving BDA and DS areas, and also enable professional to sharpen their skills aligned with job market requirements.

**2 - Deception or Truth? The Impact of Linguistic Cues to Fraud on Capital-giving Willingness: Evidence from Crowdfunding Market**

Xicheng Yin, Tongji University, Shanghai, China, Wei Wang, Kevin Zhu, Hongwei Wang, Pei Yin, Wei Chen

We adopt the following indicators to measure the linguistic cues to fraud: Cognitive Load, Internal Imagination, Dissociation, Negative Emotion, Lexical Diversity, Lexical Ease of Read, Lexical Complexity and New Word Ratio as well. Locational prepositions and temporal prepositions in reward statement, non-first-person prepositions in blurb and reward statement, and cohesion in project description normally result in successful campaigns. The concreteness of blurb and detailed description makes the project look like a deception. We provide a method to detect linguistic cues to fraud on crowdfunding campaigns and provide suggestions to project founders to better describe their projects.

**3 - Knowledge Mining in Scientific Literature for Complex Social Problems: An Example using Multi-stakeholder Performance Management**

Victor Zitian Chen, University of North Carolina, Charlotte, NC, United States, Reza Mousavi, Wlodek Zadrozny

The volume of scientific publications and the degree of knowledge fragmentation creates information overload problems and makes knowledge synthesis for solving complex social problems exceedingly difficult. Built on text mining techniques and keyword dictionaries, we develop a literature review algorithm to automate the search, comparing, and grouping of predictors of corporate performance measures from multiple stakeholders' perspectives (customers, employees, societies, and investors).

**4 - Expanding a Theoretical Model with Survey Simulations**

Seyede Yasaman Amirikiaee, PhD Candidate and Teaching Fellow, University of North Texas, 1307 West Highland Street, BLB 357D, Denton, TX, 76201, United States, Nicholas Evangelopoulos

Traditional survey design involves iterations of instrument development steps that include assessments of item reliability, and construct convergent and discriminant validity. These iterations are time consuming and tend to overuse human subjects. In an effort to economize on these resources, this research uses traditional survey methods to fit a theoretical model for the intention to ride a self-driving vehicle, and then expands the model to include additional constructs by performing survey simulations that do not involve human participants.

**5 - Topic Modelling for Medical Prescription Fraud and Abuse Detection**

Babak Zafari, Babson College, Babson Hall 218C, Babson Park, MA, 02457, United States, Tahir Ekin

Medical prescription fraud and abuse has been a pressing issue in the U.S. resulting in large financial losses and adverse effects on human health. In this work, we use the real world Medicare Part D prescription data to analyze prescriber-drug associations. In particular, we propose the use of topic models to group drugs with respect to the billing patterns and exhibit the potential aberrant behaviors. The prescription patterns of the providers are retrieved with an emphasis on opioids, and aggregated into distance based measures which are visualized by concentration functions. This output can enable medical auditors to identify leads for audits of medical providers.

## ■ WD66

West Bldg 105A

**Practice - Quality Management & Applications**

Contributed Session

Chair: Bhupesh Shetty, University of Iowa, Iowa City, IA, 07030, United States

**1 - Real-time Data-driven Monitoring for High Dimensional Multistage Manufacturing Process**

Mohammadhossein Amini, PhD Candidate, Kansas State University, 2061 Rathbone Hall 1701B Platt St, Manhattan, KS, 66506, United States

Today's manufacturing processes are much more complex including multiple stages, and sensors are embedded throughout the processes that generate a huge amount of data in high dimensions. However, current quality engineering practices still do not efficiently use the generated data. This study aims to develop predictive models using machines production data to monitor the high dimensional multistage process in real-time.

**2 - Dual Response Surface Optimization of One Side Single Quality Characteristic Using the CPK Process Indicator Index**

Michael Bendersky, Ben Gurion University of the Negev, Beersheba, Israel

Dual Response Surface methodology is a powerful tool for simultaneously optimizing the mean and the variance of a quality characteristic in the field of quality engineering. The optimization of dual response systems in order to achieve better quality has played a major role in the design of industrial products and processes. In this work we derive a new method to optimize the mean and variance of a product or process defined by a single quality characteristic and has a one sided specification limit. For this aim, we suggest the usage of the process capability index as the objective function to find the optimal values of the control variables thus allowing to maximize the yield of the process.

**3 - An Image Based Multivariate EWMA Control Chart with PCA for Faults Detection under Multiple Capturing Settings**

Shengfeng Chen, Western Michigan University, Kalamazoo, MI, 49008, United States, Lee Wells

Machine vision systems are increasingly being used in manufacturing shop floor in product quality control. Our approach extends the current research that use only one image capturing setting for fault detection. As image quality can be affected by light intensity, color and glare, we propose multiple capturing settings for better fault detection. In addition, the use of a multivariate EWMA for monitoring industrial products in conjunction with PCA analysis are used to deal with the increased data dimensions. Extensive computer simulations show that the proposed multiple capturing settings outperform the single capturing setting with greater in-control and out-of-control ratios.

**4 - Identifying Sources of Assignable Error via Process Pattern Mining**

Bhupesh Shetty, PhD Student, University of Iowa, Iowa City, IA, 52245, United States, Nick Street, Jeffrey W. Ohlmann

We explore the problem of identifying the root cause of product defects using event logs in a manufacturing process. We use a pattern mining algorithm based on Apriori to identify frequent patterns, and use binary correlation measures to identify patterns associated with elevated error rate. We design a simulation model to generate synthetic datasets to test our algorithm. We compare the effectiveness of different correlation measures, target pattern complexities, and sample sizes with and without knowledge of the underlying process. We show that knowledge of the underlying process helps in identifying the pattern that is associated with defects.

## ■ WD67

West Bldg 105B

**Aggregation of Preference Data**

Sponsored: Information Systems

Sponsored Session

Chair: Adolfo Raphael Escobedo, Arizona State University, Tempe, AZ, 85287-8809, United States

**1 - A New Integer Programming Formulation and Refined Social Choice Property for Expediting the Solution to the Consensus Ranking Problem**

Yeawon Yoo, Arizona State University, Tempe, AZ, United States, Adolfo Raphael Escobedo

We introduce an integer programming formulation for ranking aggregation with ties and compare it to a modified version of a recently developed formulation. This new formulation provides computational advantages when solving large size problems. Moreover, we develop a refined social-choice related property for group decision-making, called the Generalized Condorcet Criterion, which can be regarded as a natural extension of the Condorcet criterion. Unlike its parent properties, it is adequate for complete rankings with ties as well as for incomplete rankings. It allows us to simplify the solution process for certain types of very large instances of the NP-hard ranking aggregation problem.

**2 - Rank Aggregation New Bounds for MCx**

Daniel Freund, Cornell University, 109 Lake St, Ithaca, NY, 14850, United States, David P. Williamson

Rank aggregation is a fundamental problem in combinatorial optimization: for a set of input rankings the goal is to find a ranking that minimizes the average Kendall tau distance to the input rankings. Proposed by Dwork et al. for metasearch engines, its applications today range far beyond the original aim to problems in ML, recommendation systems and more. Though several algorithms, including a PTAS, have been proposed for these problems, it is known that some Markov chain based algorithms perform extremely well in practice. In this talk we, somewhat surprisingly, prove supra-constant lower bounds on approximation guarantees for all of them.

**3 - Joint Aggregation of Cardinal and Ordinal Evaluations**

Adolfo Raphael Escobedo, Arizona State University, P.O. Box 878809, Tempe, AZ, 85287-8809, United States, Dorit Simona Hochbaum, Erick Moreno-Centeno

An important problem in decision theory concerns the aggregation of individual cardinal and ordinal evaluations (ratings and rankings). We illustrate a new aggregation framework in the context of the 2007 MSOM's student paper competition, which posed two unique challenges: (1) each paper was reviewed by relatively few judges, heightening the potential influence of subjective scales; (2) each judge submitted both cardinal and ordinal evaluations of their assigned papers. To address these challenges, we employ axiomatic distances and derive new non-convex exact formulations and convex relaxations. The solution methodologies are further tested and analyzed via randomly generated instances.

**4 - Elaborating or Aggregating? The Joint Effects of Group Decision-making Structure and Systematic Errors on the Value of Group Interactions**

Wenjie Tang, NUS Business School, 15 Kent Ridge Dr, Singapore, 119245, Singapore, Steffen Keck

We explore when group interactions will have a positive effect on the accuracy of quantitative judgments. The results from two laboratory experiments revealed that compared to a statistical aggregation of individual judgments, group interactions only provide values when the level of systematic error is high and when there is a designated group leader. Moreover, our analysis showed that this effect was mediated by information elaboration which was generally higher in leader groups but only had a significant effect on the value of group interactions when there was a high level of systematic error among group members, and not otherwise.

## ■ WD68

West Bldg 105C

**Joint Session QSR/Practice Curated: Data Analytics in Complex Systems: Methodology and Applications**

Sponsored: Quality, Statistics and Reliability

Sponsored Session

Chair: Changyue Song, University of Wisconsin-Madison, Madison, WI, 53715, United States

**1 - A Cross-study Analysis for Reproducible Sub-classification of Mild Traumatic Brain Injury**

Bing Si, Arizona State University, Mesa, AZ, 85201, United States

The current stratification of traumatic brain injury (TBI) into "mild", "moderate", or "severe" does not adequately account for the patient heterogeneity. The

objective of this study was to identify reproducible clusters of mild TBI patients based on rich data available at the time of the initial post-TBI patient evaluation. A sparse hierarchical clustering is applied to simultaneously select informative variables and identify underlying clusters with selected variables. Two independent datasets were utilized. Clusters found in one dataset are tried to be reproduced in another dataset. Reproducible clusters with different patient outcomes could be used to guide mTBI patient prognosis.

**2 - Recent Advances in Calibration of Computer Models**

Rui Tuo, Atlanta, GA, 30318, United States

In this talk I will show some recent advances in calibration for computer models and an application example. The goal of calibration is to identify the model parameters in deterministic computer experiments, which cannot be measured or are not available in physical experiments. In a study of the prevailing Bayesian method we find that this method may render unreasonable estimation for the calibration parameters. Inspired by a new advance in Gaussian process modeling, called orthogonal Gaussian process models, I have proposed a novel methodology for calibration. This new method is proven to enjoy nice properties.

**3 - Modeling and Change Detection for Count-weighted Multi-layer Networks**

Hang Dong, Tsinghua University, Beijing, 100084, China, Nan Chen, Kaibo Wang

In a typical network with a set of individuals, it is common to have multiple types of interactions between two individuals. In practice, these interactions are usually sparse and correlated, which is not sufficiently accounted for in the literature. This work proposes a multi-layer weighted stochastic block model (MZIP-SBM) to characterize the sparse and correlated interactions of individuals among different layers. A variational-EM algorithm is developed in order to estimate the parameters in this model. We further propose a monitoring statistic based on the score test of model parameters for change detection in multi-layer networks and evaluate the performance of this method.

**4 - An Effective and Efficient Algorithm for Moving Targets Detection and Tracking with a Moving Camera**

Yinwei Zhang, University of Arizona, Tucson, AZ, United States, Young-Jun Son, Jian Liu

Detecting and tracking moving targets with video surveillance systems is challenging, especially when using a moving camera. Conventional algorithms using projective transformation and frame differencing are inaccurate and slow. A new algorithm that combines a type of optical flow and color features is proposed to improve both detection accuracy and tracking speed. Case studies of a variety of complex scenarios were conducted to demonstrate its effectiveness and efficiency.

## ■ WD69

West Bldg 106A

**Joint Session QSR/Practice Curated: Blockchain Study and Application**

Sponsored: Quality, Statistics and Reliability

Sponsored Session

Chair: Hong Wan, Purdue University, West Lafayette, IN, 47907, United States

**1 - A Mechanism Design Approach to Blockchain Protocols**

Hong Wan, Purdue University, West Lafayette, IN, 47907, United States, Abhishek Ray, Mario Ventresca, Xinqi Gao

Blockchain-based systems such as cryptocurrencies are achieving widespread usage, with a market capitalization of \$150B as of September 2017. However, the most prominent platforms that account for over 70% of this market - Bitcoin & Ethereum - are exhibiting increasingly lower levels of decentralization. This poses the problem of concentrating levers of consensus to a select group of agents in the system. Essentially, centralization in a system designed to be decentralized can lead to security threats such as 51% attack. In this paper, we demonstrate the use of game theory and mechanism design to find ways of solving the problem of centralization in blockchain systems. Since decentralization vs centralization is related to non-cooperative vs. cooperative behavior, using simple models based on non-cooperative and cooperative game theory we propose a way of designing payoffs in order to disincentivize certain exhibited behaviors and incentivize desired behaviors of miners or validators in such systems.

### 3 - BitExTract: Interactive Visualization for Extracting Bitcoin Exchange Intelligence

Siyuan Liu, Pennsylvania State University, University Park, PA, United States

The emerging prosperity of cryptocurrencies, for example, Bitcoin, has come into the spotlight during the past few years. In this paper, we present BitExTract, an interactive visual analytics system, which, to the best of our knowledge, is the first attempt to explore the evolutionary transaction patterns of Bitcoin exchanges from two perspectives, namely, exchange versus exchange and exchange versus client. The effectiveness and usability of BitExTract are demonstrated through three case studies with novel insights and further interviews with domain experts and senior Bitcoin practitioners.

## ■ WD70

West Bldg 106B

### Practice - Computer Science – Applications to OR

Contributed Session

Chair: Hiroko Okajima, Towson University, 8000 York Road, Towson, MD, 21252-0001, United States

#### 1 - On the Consistency and Computation of Maximum Likelihood Estimators for Multivariate Hawkes Processes

Anran Hu, PhD Student, UC Berkeley, Albany, CA, 94706, United States, Xin Guo, Renyuan Xu, Junzi Zhang

We establish the first consistency result for the maximum likelihood estimators (MLEs) of multivariate Hawkes processes (MHPs) with general linear intensity processes, under mild and verifiable conditions. We also develop an alternating minimization type algorithm with guaranteed global convergence to the set of critical/stationary points. The performance of the proposed algorithm on both synthetic and real-world data is reported, showing the advantage of our approach.

#### 2 - Balance Optimization Subset Selection with Multiple Treatment Levels

Hee Youn Kwon, Northwestern University, 2211 Campus Drive, Evanston, IL, 60208, United States, Jason J. Sauppe, Sheldon H. Jacobson

Matching and Balance Optimization Subset Selection (BOSS) are two frameworks for causal inference with observational data. These methods find an estimate for the treatment effect either by matching each treatment unit to a control unit or by finding a control group that is balanced with respect to the treatment group. However, when there are multiple - more than two - treatment levels, methods of comparing two levels are not directly applicable. The goal of this talk is to generalize the BOSS framework which was developed under a binary treatment setting to a multi-treatment setting. The BOSS estimator is computationally compared to the matching estimators.

#### 3 - A Balancing Block Based Formulation for the Police Districting Problem: The Case of Antofagasta Police Department

Evelyn Arrey, Universidad Catolica del Norte, Avenida Angamos 0610, Building Y1, Antofagasta, Chile, Hernan Caceres

Preventive security is one of the most critical social priorities of a community, for which a typical strategy is to design patrol areas. Such designs consist on dividing a city according to one or several features of its neighborhoods, that are area-based indicators in most cases. In this work, we propose a mixed integer program that splits an urban area by balancing a cumulative block-based indicator among a given number of sub-divisions. For our numerical example, we present a case study of the Police Department of Antofagasta, Chile. We compare our results with the division that the city currently uses, that is based on the nation-wide program Quadrant Plan.

#### 4 - Can Group Giving Boost Contribution?

Hiroko Okajima, Assistant Professor, Towson University, 8000 York Road, Towson, MD, 21252-0001, United States

Group giving (collective giving) has been gaining popularity in practice, but little has been studied in literature. This study supplements the existing literature by providing empirical results on group giving. Our laboratory experiment reveals that group giving is especially effective in increasing giving rates when it is used in combination with stepwise rebates.

## ■ WD71

West Bldg 106C

### Combinatorial Optimization over Graphs

Sponsored: Computing

Sponsored Session

Chair: Illya V. Hicks, Rice University, Houston, TX, 77005-1892, United States

#### 1 - Catching a Robber Quickly with Few Cops

Boris Brimkov, Rice University

Cops and Robbers is a pursuit-evasion game played on a graph, between a team of cops and a single robber. The cops and the robber take turns moving to adjacent vertices; the goal for the cops is to capture the robber by occupying the same vertex as the robber, and the goal of the robber is to avoid capture. We consider the cop-throttling number of a graph  $G$ , which is defined as the minimum possible value of  $(k + \text{the minimum number of turns needed for } k \text{ cops to capture the robber on } G \text{ over all possible games})$ . This talk will provide some tools for computing and bounding the cop-throttling number, and relate it to other graph parameters.

#### 2 - SAT and SMT Encodings of the Zero Forcing Problem

Derek Mikesell, Rice University, Houston, TN, United States

Zero forcing is an iterative graph coloring process in which a colored vertex forces a neighboring vertex to be colored if it is the only uncolored vertex in its neighborhood. The Zero Forcing Problem asks for the smallest set of initially colored vertices such that the entire graph becomes colored under this rule. In this work, computational methods are proposed for the Zero Forcing Problem and related variants. The methods are based on a Boolean Satisfiability and Satisfiability Modulo Theories encoding of an infection model. The methods yield competitive results to state-of-the-art integer programming and combinatorial algorithms.

#### 3 - A Set Cover Formulation for Power Domination in Graphs

Logan Smith, Rice University, Houston, TX, United States

To observe electrical networks, sensors are installed at power substations. Sensors directly observe adjacent substations and may indirectly observe others. In graphs representing power grids, vertices corresponding to substations with sensors are initially colored; the power domination color rule indicates which substations are observable. Previous computational methods rely on modeling the coloring rules and vertex coloring sequences. Here, an alternative exploiting graph structures that prevent colorings is introduced. Unlike previous work, this approach permits a separation algorithm. Computational experiments show significant runtime improvement for the proposed algorithm.

## ■ WD72

West Bldg 211A

### Practice- Operations/ Marketing Interface

Contributed Session

Chair: Jinpeng Xu, Xidian University, School of Economics and Management, Xi'an, 710126, China

#### 1 - Supply Network Effects on the Scalability of Online Grocery Retail Platforms

Lina Wang, Student, Arizona State University, Tempe, AZ, 85257, United States, Timothy Richards, Elliot Rabinovich

A grocery retail platform acts as a two-sided market connecting consumers and suppliers. Its scalability depends on the type and the number of vendors participating in the platform. We study empirically indirect network effects on scalability in one of these platforms. Whether these effects are positive will depend on the impact that the number and types of vendors participating in the platform have on consumers' demand. Results obtained from a consumer demand model and a supply provision equilibrium model confirm the existence of a positive indirect network effect on the scalability of these platforms.

#### 2 - Keep the Buzz and Binge on Optimal Content Release Strategies

Clint Ho, Imperial College Business School, London, SW2 7AZ, United Kingdom, Esma Koca, Wolfram Wiesemann

Video-on-demand platforms unveiled a game-changing media consumption phenomenon, binge-watching, with the release of all episodes of series at once (entire season at once policy) and hence generate a binge-watching driven buzz among viewers. As opposed to this, traditional strategy (episodic release strategy) creates a viewer-generated chatter around the story, commonly called as the water-cooler effect. We argue that a hybrid and a personalized strategy may activate both levers and investigate three aspects of the optimal content release: (1) optimal release of a series, (2) optimal order of multiple series, and (3) discrimination on the content across heterogeneous viewers.



### 3 - Entry of Pseudo Sharing

Siyi Wang, University of Science & Technology of China, Hefei, China

Pseudo sharing—the phenomenon of professional agents participating in the sharing market—has caused a huge uproar among the affected traditional markets and governments. It exists in different sharing platforms that involved in different mechanisms. We develop a game-theoretic model to exam the sharing platforms' interaction with pseudo sharers, as well as the genuine one. Our equilibrium results suggest that, to some extent at least, it enhances the matching rate when the clutter of genuine sharing supply and demand caused most occasional transaction failed.

### 4 - When Should Retailers Integrate Online and Offline Channels Under Competition?

Jinpeng Xu, Xidian University, School of Economics and Management, Xi'an, 710126, China, Yufei Huang

This paper considers two multichannel retailers selling a product to consumers with different channel preferences. Retailers can choose to operate their online and offline channels separately, with different prices and unit costs in different channels. They can also choose to integrate the two channels, thereby achieving the same price and unit cost in different channels. We use a game-theoretical model to study when one or two retailers should integrate their channels in competition.

### 5 - Product Quality Decision and Return Channel Choice with Uncertain Demand

Buqing Ma, Doctor Student, University of Science and Technology of China, Baohe District, hefei, Anhui province, China, Hefei, 230035, China, Yunchuan Liu

The practice of accepting product returns from consumers directly is understudied in previous literature where consumers return products to manufacturers through retailers. In this paper, we study a manufacturer's return channel choice and product quality decision with demand uncertainty, and find some interesting relationship between product qualities, return channel choice, and demand uncertainty.

## WD73

West Bldg 211B

### Semiconductor Industry

Contributed Session

Chair: Maryam Anvar, Applied Materials, San Jose, CA, 95125, United States

#### 1 - Minimizing Robotic Arm Travelling Distance for LED Sorting Problem

Jo-Ying Chang, National Chiao Tung University, 1001 University Road, Hsinchu, 300, Taiwan, Lo-Min Su, Sheng-I Chen

The LED sorting problem is to determine a sequence to transfer dies from a wafer to bins in different quality levels. The objective is to minimize traveling distance of a robotic arm that is used for classifying LED dies. This problem can be seen as the hierarchical travelling salesman problem. We propose a two-stage algorithm, where the sequence of picking same quality level dies is solved in the first stage, and the shortest distance to connect adjacent tours is determined in the second stage. The results demonstrate the capable of the proposed algorithm to solved real-world cases.

#### 2 - Modeling and Solving LED Dies Picking Problems

Sheng I. Chen, National Chiao Tung University, 1001 University Road, HsinChu, 30010, Taiwan, W.L. Pearn, Yen Che Tseng, Wei Ting Hsu

We consider LED dies picking problem as a graph representation, where each die refers to a node and the objective is to find a shortest walk covered all nodes in a fully connected graph. To reduce the problem size, we transform adjacent nodes located at the same column as a required arc and each pair of vertexes connected two different columns as a non-required arc. The optimization problem is formulated as a rural postman problem (RPP). We propose an algorithm for solving the RPP. Computational results compare both exact and approximate solutions using general die distributions.

#### 3 - On Mathematical Models of Optimal Video Memory Design

Yiwen Xu, Assistant Professor, North Dakota State University, 1410 14th Avenue North, Room 202 Civil & Industrial Engineering, Fargo, ND, 58102, United States

The big video data size today imposes huge pressure on storage. Designing memory is a challenging problem due to design constraints, multiple memory bitcell design options, and layout integration under different memory technologies. We develop mathematical models for optimizing embedded video memory design without applying a traditional time-consuming and laborious ASIC design process. The problems are formulated as nonlinear programs and integer linear programs. Different SRAM designs and hybrid SRAM and DRAM designs are considered in our models. The numerical studies show that by applying our proposed method the average mean square error of the video storage can be greatly reduced.

#### 4 - A Branch-and-price Algorithm for Solving Multi-site Production Planning Problem in TFT-LCD Manufacturing

Yen-Che Tseng, National Chiao Tung University, Hsinchu, Taiwan, Hsin-Lan Tseng, Sheng-I Chen

We study the production planning problem with multiple products and multiple plants for a TFT-LCD manufacturer. A MIP model is formulated to determine production quantity at each plant with the considerations of inventory, capacity, and materials. This problem can be viewed as an extension of generalized assignment problem (GAP), where each customer order corresponds to a task and each factory refers to an agent of a typical GAP problem. A branch-and-price algorithm is implemented for solving large-scale problem instances. We develop a parallel computational framework for solving pricing problems, as well as discover dominance relations between scenarios to enhance runtime.

#### 5 - A Parallel Search Algorithm for Solving LED Sorter Scheduling Problem

Wei-Ting Hsu, National Chiao Tung University, Hsinchu, Taiwan, Chang-Feng Li, Sheng-I Chen

This study considers the assignment of wafers to identical machines in LED sorting. A mixed integer programming (MIP) model is presented with the objective to minimize the completion time of sorting and merging processes. We reformulate the MIP as upper-bound feasibility problems and each feasibility problem is evaluated using a parallel environment. To enhance run time, we further propose a hybrid method including reducing the problem size by predetermining decision variables, recovering infeasibility, and applying valid inequalities. Finally, a bi-sectional search scheme is adapted for exploring problem instances that exceeded the runtime limit.

#### 6 - Queue Time Simulation

Maryam Anvar, Industrial Engineer, Applied Materials, Santa Clara, CA, United States

A typical wafer process flow contains up to 1,000 individual steps. Some of these steps have time-sensitive processes which limit the queue time between consecutive operations. Wafers that exceed the time limit will either be scrapped or will experience significant yield loss. In this paper, we use a series of simulation experiments to study the effects of these time limits on wafer scraps and tool capacity to understand and quantify the relationship between tool capacity, lot cycle times through these steps, and the associated rate of time limit violations.

## WD77

West Bldg 213A

### Practice- Modeling for Complex Systems I

Contributed Session

Chair: George C. Mytalis, CUNY, New York, NY, 11209, United States

#### 1 - Building Total Cost of Ownership Model for Power Battery Consumer

Chunyan Duan, Tongji University, Room 1114, Tongji Building A, Siping Road 1500, Shanghai, 200092, China  
Chunyan Duan, University of Arkansas, Fayetteville, AR, 72701, United States, Jianxin You, Hu-Chen Liu, Luning Shao, Mengmeng Shan

Power battery's economic performance is the main influence on the economic performance of the electric vehicle. We are modeling power battery consumer's total cost ownership by applying the mathematical modeling method, and exploring the factors of the power battery consumer's total cost ownership and its relationship between these factors under the fast charging mode and the slow charging mode.

#### 2 - Continuous-time Principal-agent Model in Regulating Disruptive Technology

Qi Luo, University of Michigan-Ann Arbor, Ann Arbor, MI, 48109, United States, Romesh Saigal, Zhibin Chen

Innovative technologies can achieve a faster penetration and therefore disrupt an existing market. For example, self-driving technology may have massive impact on the transportation network, and consequently the government needs to regulate the market by financial subsidies. We study the decentralized decision-making problem as a principal-agent model in continuous time. The market dynamics is described by the diffusion of innovation and the problem can be converted to solving a Hamilton-Jacobi-Bellman (HJB) equation. Similar applications include the regulations of new drugs, electric vehicles and wireless networks.

**3 - Dynamic Tracking of Software Errors: A Big Data Approach**

John G. Wilson, Professor, Ivey Business School, 1255 Western Road, London, ON, N6G 0N1, Canada, Dov Te'eni

In the internet age, a proliferation of services appear on the web. Errors in using the internet service or app are dynamically introduced as new devices/interfaces/software are produced. The number of users who can detect various errors changes dynamically. Allowing new users and errors to enter dynamically poses considerable modeling and estimation difficulties. In the era of Big Data, methods for dynamically updating as new observations arise are important. We provide a general model that allows for a procedure for finding maximum likelihood estimators of key parameters where the number of errors and the number of users can change.

**4 - Aggregate Production Planning in Stochastic Manufacturing Systems: A Simulation Study**

Gerd J. Hahn, Professor, German Graduate School of Management and Law, Bildungscampus 2, Heilbronn, 74076, Germany

This paper studies the issue of integrated capacity and batch planning in stochastic manufacturing systems. Classical mathematical programming-based approaches to production planning typically omit the impact of variability on the performance of manufacturing systems. Therefore, a hierarchical planning approach is presented that integrates a queuing network model to anticipate the stochastic behavior of the manufacturing system. A simulation study is conducted to show the benefit of this approach using a real-life case example.

**5 - A Queueing System with Disaster Events under Different Policies**

George C. Mytalas, CUNY, New York, NY, 11209, United States

We consider an M/G/1 queueing system with batch arrivals subject to disasters and server breakdowns under N-policy. The server is turned off as soon as the system empties. When the queue length reaches or exceeds a value N (threshold), the server is turned on and begins to serve the customers. When a disaster occurs the system is cleared of all customers and the server initiates a repair period. During the repair period arriving batches of customers accumulate in the queue without receiving service. Besides, the server has an exponential lifetime in addition to the catastrophe process.

**■ WD78**

West Bldg 213B

**Humanitarian Operations Management**

Sponsored: Public Sector OR

Sponsored Session

Chair: Alfonso Pedraza Martinez

Co-Chair: Telesilla Olympia Kotsi, Bloomington, IN, 47401, United States

**1 - Food Aid Modality Selection Problem**

Feyza Guliz Sahinyazan, McGill University, Desautels Faculty of Management, Bronfman Building, 1001 Rue Sherbrooke O, Montreal, QC, H3A 1G5, Canada, Marie-Eve Rancourt, Vedat Verter

Delivering food aid to rural areas requires significant operational effort by the aid agencies. Empirical evidence shows that implementing cash and voucher programs can decrease the logistics costs, improve the nutritional outcomes, and contribute to the local economy. In this paper, we develop a model that selects the aid modality by measuring the improvements in these three program objectives. We also incorporate the consumption behaviour of the beneficiaries in a bilevel optimization model structure to capture their cash spending preferences and solve the problem for Garissa county of Kenya.

**2 - Allocation of Nonprofits' Funds among Program, Fundraising, and Administration**

Telesilla Olympia Kotsi, Bloomington, IN, 47401, United States, Goker Aydin, Alfonso J. Pedraza-Martinez

Nonprofits allocate their budget among three types of expenses: program spending to deliver services to beneficiaries; fundraising spending to raise donations; and administration spending to build infrastructure. We analyze how a nonprofit can balance the immediate reward of program spending versus the future reward of fundraising and administration spending. We determine when program spending becomes relatively more attractive, perhaps at the expense of fundraising and administration spending, and vice versa. Our case study uses IRS data to show that budget allocation decisions reflect nonprofits' choices about the most appropriate type of assistance to help beneficiaries.