Ministry of Infrastructure
and Water Management

Performance Based Navigation (PBN) roadmap for the Netherlands

2020-2030

Foreword

February 2021

I am proud to present to you the new Performance Based Navigation (PBN) Roadmap for the Netherlands 2020-2030. It has been over 10 years since the release of the previous PBN Roadmap. The PBN landscape has changed significantly over those 10 years. On the international level we have seen mandates set with the introduction of the PBN Implementing Rule. Nationally, the new Luchtvaartnota 2020-2050 was published and a program for redesigning the Dutch airspace was started, with both of them relying on PBN to achieve some of their goals. Meanwhile the program to introduce PBN procedures at all Dutch airports is making significant progress, which in turn makes it possible to decommission older navigational aids. Regarding noise reduction we have recently seen the implementation of a RNP night transition approach to runway 18C at Schiphol. With so many advancements taking place it was the right time to look ahead and come up with a new roadmap.

This roadmap has been commissioned by the Performance Based Navigation Task Force (PBN TF) under the leadership of the Directorate General of Aviation and Maritime Affairs of the Ministry of Infrastructure and Water Management. The writing team consisted of MovingDot, Adecs and ADSE. The PBN TF has been established in 2008 and has been working on further implementation of PBN in the Netherlands ever since. The PBN TF consisted of the following organisations: Ministry of Infrastructure, Ministry of Defense, Royal Netherlands Air Force, LVNL, Civil Aviation Authority, Military Aviation Authority, KLM, Transavia, Amsterdam Airport Schiphol, CHC Helicopters and NLR. It is because of the dedicated commitment of the organisations and their representation participating in the PBN TF, that a consolidated vision and roadmap has been established.

During the course of writing this roadmap many stakeholders have been consulted. I want to thank all the stakeholders involved for their time and commitment. Because of corona restrictions a physical symposium was not possible. Due to the flexibility of the writing team we were able to organize a successful webinar instead.

As PBN is becoming an ever more integral part of our air traffic management system I am confident that this new roadmap provides us with a firm basis for further PBN implementation in the Netherlands.

Arjan Vermeij
Chairman of the PBN Task Force

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Executive summary

The Air Traffic Management (ATM) system of the Netherlands is facing major changes instigated by international developments such as SESAR, NextGen and the continued global harmonisation as pursued by ICAO. One of the fundamental changes in the ATM system is the gradual move towards a system that is based on trajectory-based operations, the management of air traffic flows instead of controlling individual aircraft and the flexible use of airspace. Performance Based Navigation (PBN) is considered to be a key enabler for the transition towards this new ATM system. Furthermore, PBN will be an integral part of the redesigned airspace of The Netherlands.

The PBN Roadmap does not stand on itself. PBN is an enabler for many other and wider ATM developments, sharing the same end goals on safety, efficiency and environmental responsibility. Additionally, concurrent developments are required for the successful implementation of PBN. These consist of operational concept development, airspace structure definition, safety analysis, interoperability analysis as well as development of the required tooling and training of personnel involved.

The main drivers for PBN implementation are regulations and strategic goals related to safety, environment, flight track predictability and airport/heliport accessibility. The strategic goals for PBN are based on the general goals for aviation by the Dutch Government, as indicated in the Luchtvaartnota and the Dutch airspace redesign program. In order to achieve these strategic goals and comply with the regulations, several PBN elements are available. These elements enable gradual implementation of PBN, tailored for the specific situation of each airport. By providing benefits for airports and airspace users, the transition towards PBN is stimulated. The elements are organized per flight phase.

ATS routes

For (fixed wing) ATS routes, the PBN specification “RNAV 5” is applicable. Currently, all ATS routes in the Netherlands are already RNAV 5 compliant. No developments are foreseen within the time scope of the roadmap (2020-2030).

Standard Instrument Departures - SIDs and Standard Arrival Routes - STARs

For SIDs and STARs, the PBN elements are defined based on RNP 1, for high traffic demand situations (Schiphol TMA airports) and RNAV 1 (other airports). Further steps involve desired developments with respect to environmental impact reduction. For RNP 1, the combination with RF-legs is foreseen to support these developments.

Approaches

For approaches, the RNP APCH and RNP AR APCH specifications form the basis upon which the PBN Approach elements for this Roadmap have been built. In addition to the two navigation specifications, three ‘supporting’ concepts are considered in the roadmap. By combining the two navigation specifications with these concepts, an increased use of the relevant PBN element is enabled:

- RNP APCH + RNP to xLS: allows RNP routings to ILS (especially for low visibility operations)
- RNP AR APCH + RNAV visual: enables non-RNP AR APCH compliant operators to fly the RNP AR APCH routings (under visual conditions)
- RNP AR APCH + Established on RNP (EoR): enables the use of independent parallel approaches (relevant for Schiphol operations only)

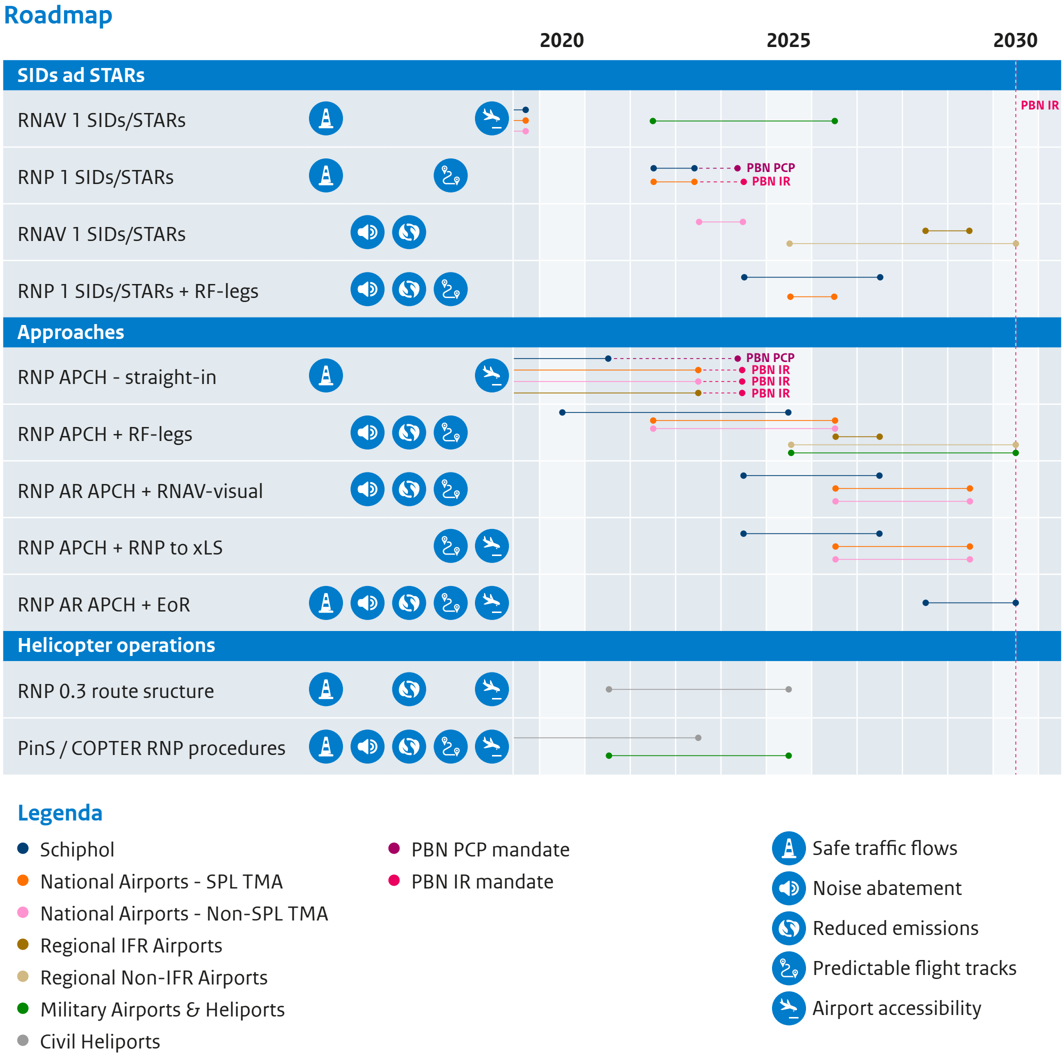
Helicopter operations

For helicopter operations, the RNP 0.3 navigation specification is the basis for the proposed PBN elements. With this specification, it is proposed to develop a low-level helicopter route structure and helicopter departures and approaches: PinS or COPTER RNP procedures.

General aviation

General Aviation traffic operating according to VFR are not directly affected by the PBN developments. However, VFR General Aviation operations might face indirect effects from PBN developments. On the positive side, airspace for VFR operations might be increased. Since commercial IFR operations will fly more accurately and follow fixed routes with PBN in the future, airspace currently reserved for these operations might be partly opened for VFR operations. On the other side, VFR traffic at these airports might experience limitations due to combined PBN/IFR and VFR operations.

Roadmap



The figure above provides an overall overview of the PBN Roadmap elements and the timing of PBN developments for all airports, airport types and the helicopter operations: The PBN Roadmap.

The existing PBN Taskforce in The Netherlands will provide oversight and guidance on PBN developments in The Netherlands in the 2020-2030 timeframe. The Ministry of Infrastructure and Water Management, as chair of the PBN Taskforce, will initiate regular PBN Taskforce meetings with all relevant stakeholders in The Netherlands. The PBN Taskforce will monitor the implementation of PBN throughout the PBN Transition Plan. The PBN Transition Plan details the PBN implementation and is to be considered a “living document” with yearly milestones for the 2020-2030 time period.

The PBN transition plan and (local/regional) PBN implementation plans will need to further specify the required and feasible investments, related developments, resources, costs and lead times associated with implementing PBN in operations.

1 Introduction

The ATM system of the Netherlands is facing major changes, instigated by international developments such as SESAR, NextGen and the continued global harmonisation as pursued by ICAO and EASA. On a national level, increasingly higher requirements for sustainability, predictability, safety and environmental impact reduction call for a novel way of performing Air Traffic Services (ATS).

One of the fundamental changes in the ATM system is the gradual move towards a system that is based on trajectory based operations, the management of air traffic flows instead of controlling individual aircraft and the flexible use of airspace. ***Performance Based Navigation (PBN) is considered to be a key enabler for the transition towards this new ATM system.***

In 2018, The Netherlands has started a joint civil-military program for redesigning its airspace. The program spans operational air traffic management concepts, airspace structure and routes as well as arrangements regarding airspace usage. The objective is to implement an integral, future-proof air traffic management system through the design and management of the Dutch airspace based on a careful weighing of interests, in cooperation with international partners and in a continuing dialogue with actively involved stakeholders. Implementation will be a continuing operation starting in 2023. The “Preferential alternative” (*Voorkeurs-alternatief*) document describes the necessary tools to achieve the objective of the program, foreseen for 2035. ***PBN will be an integral part of the redesigned airspace of The Netherlands. The PBN Roadmap has been written in cooperation with this program.***

Implementation guidance for PBN has been made available by ICAO[1], Eurocontrol[2] and CANSO[3]. The PBN roadmap 2010-2020[4] for the Kingdom of the Netherlands (including the Caribbean region) was produced by the Dutch PBN Task Force under the leadership of the Directorate General of Civil Aviation and Maritime Affairs of the Ministry of Transport and Water Management. Inherent to changes to the ATM system are the relatively long lead times to achieve the targets described in the PBN roadmap. However, benefits of applying PBN can already be seen in present day operations in the Netherlands.

This document sets out a roadmap for PBN for the Netherlands for the period of 2020-2030. Ultimately, the roadmap leads to a seamless transition towards the SESAR concept and the global harmonisation of the ATM system. Additionally, the PBN roadmap builds upon the requirements of the European PBN implementing rule in this context.

This PBN Roadmap document should be read and used in close combination with the PBN Transition Plan of The Netherlands[5]. The Transition plan focuses on the transition period between now and 2030 and is a formal document required by EU legislation. It details how the PBN implementation will be done in accordance with regulations, including the description of transitional measures.

1.1 Rationale and scope

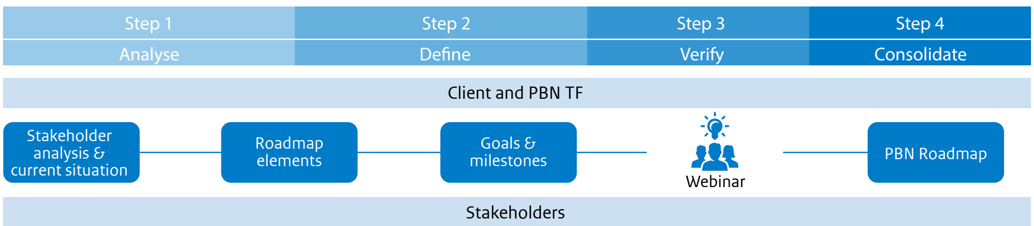
This document formulates the ambition and major milestones with respect to PBN for the period 2020-2030 and a rationale for these targets to expedite the implementation process. This roadmap covers PBN from commercial, military and general aviation perspectives, with a focus on the developments at all Dutch airports and heliports.

The PBN roadmap 2020-2030 builds upon the initial roadmap and provides developments, benefits, challenges and goals for the coming decade with respect to the implementation of PBN in The Amsterdam Flight Information Region (FIR).

1.2 Approach / working method

Figure 1 below indicates the main steps and tasks that were carried out in order to determine this PBN Roadmap.

Figure 1 Steps undertaken to determine the PBN Roadmap



Over 40 stakeholders from The Netherlands and neighboring countries were consulted. Questionnaires and conversations were used to determine stakeholder specific PBN requirements, and translated to strategic goals, PBN elements and milestones. The contacted stakeholders were from a wide range of relevant PBN parties such as the ANSPs (LVNL, CLSK, MUAC), military, airports, airlines, flight schools, and aviation associations.

In addition, existing PBN roadmaps / plans from other countries (e.g. France, Belgium, USA, UK) have been reviewed. These roadmaps present approaches and methodologies which are comparable to the PBN Roadmap presented in this document. ***The reviewed roadmaps were also used as a reference to define this ambitious, yet realistic, roadmap covering a complete set of relevant PBN aspects***.

Once the preliminary roadmap elements and timeline were established, an interactive webinar was hosted where stakeholders could attend and provide their feedback, thoughts and comments on the draft roadmap for verification purposes. Finally, after the webinar, a final consolidation of all additional feedback and changes was undertaken. This culminated in the final PBN Roadmap, in the form of this document.

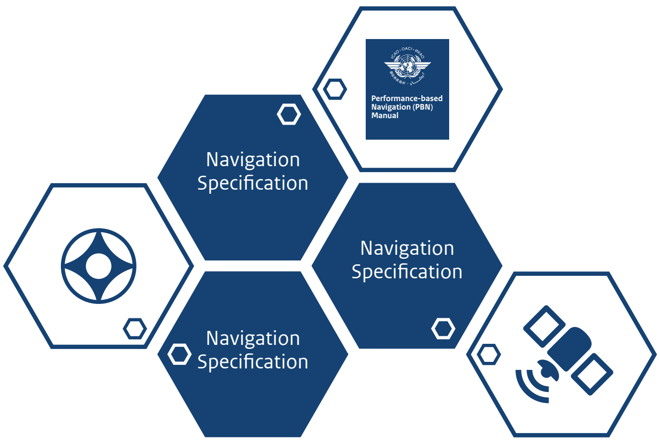
2 The PBN concept

2.1 PBN explained

PBN is defined as: ***area navigation based on performance requirements for aircraft operating along an ATS route, on an instrument approach procedure or in a designated airspace***[1].

PBN enables Air Navigation Service Providers (ANSPs) and airports/heliports to implement optimal routes, independent of the location of (conventional) ground-based navigation systems.

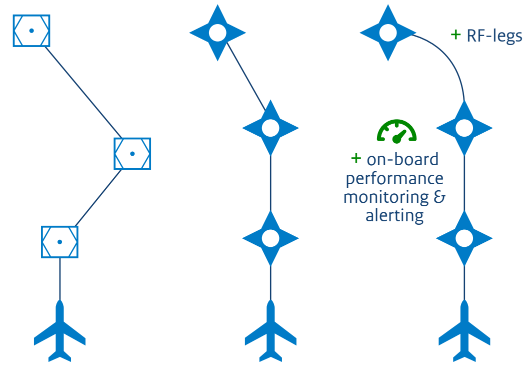
Figure 2 PBN components



PBN is based on three components: The Navigation Specification, the Navigation Infrastructure and the Navigation Application, as shown in Figure 2.

The ***Navigation Specification*** stipulates the performance requirements in terms of accuracy, integrity and continuity for proposed operations in a particular airspace. There are currently two groups of Navigation Specifications: Required Navigation Performance (RNP) and Area Navigation (RNAV). The number after RNAV/RNP refers to functional and performance requirements of that navigation specification. RNP includes a requirement for on-board performance monitoring and alerting, while an RNAV specification does not. Furthermore, the RNP specification enables the use of Radius-to-Fix (RF) legs. For an illustration of differences, see Figure 3.

Figure 3 Conventional navigation versus RNAV/RNP



The detailed definitions of the PBN Navigation Specifications can be found in ICAO DOC 9613.[1]

The ***Navigation Infrastructure*** relates to ground- or space-based navigation aids that are defined in the Navigation Specification.

The ***Navigation Application*** defines instrument flight procedures in a defined airspace. The Navigation Application can only be executed if the correct Navigation Infrastructure is available.

ANSPs can define the various Navigation Applications through the Airspace Concept. Airspace can be labelled RNAV 1 Airspace for example, which means aircraft need to be able to adhere to the RNAV 1 Navigation Specification. Similarly, ANSPs can define an RNP APCH for a certain runway in a defined airspace. When airspace is PBN labelled or a PBN approach is published, aircraft can enter the PBN labelled airspace or fly the published PBN approach if both the aircraft and flight crew are qualified and compliant to the Navigation Specification.

2.2 Regulations

The main drivers for PBN implementation are regulations and strategic goals related to safety, environment, flight track predictability and airport/heliport accessibility. The regulations come from ICAO, the European Commission and national policy. The strategic goals are elaborated in section 2.3.

ICAO regulations

ICAO has published the Global Aviation Navigation Plan (GANP) in 2016[6], supported by the State of the Netherlands. The GANP describes PBN as "Our Highest implementation priority". ICAO sees the implementation of PBN in terminal airspace as a key enabler for advanced terminal operations. Furthermore, ICAO provides guidance to States for the implementation of PBN. The ***PBN Manual (Doc 9613)***[1] provides the background and detailed technical information required for operational implementation planning, and a large set of navigation applications.

European Commission regulations

Commission Implementing Regulation 2018/1048[7] is the *PBN Implementing Regulation (PBN IR)*, which aims to answer ICAO's Global Air Navigation Plan (GANP) and the European ATM Master Plan. The PBN part of this regulation mandates:

- By 3rd December 2020: All non-precision instrument runway ends will have RNP approach. ATS routes above FL150 shall be RNAV 5. Rotorcraft procedures shall be RNP 0.3, RNAV 1 or RNP 1.
- By 25th January 2024: All precision runway ends will have RNP approach. For SIDs and STARs, at least one SID or STAR per runway ends shall be RNAV 1. ATS routes below FL150 shall be RNAV 5.
- By 6th June 2030: All SIDs and STARs shall be RNAV 1, and there shall be exclusive use of PBN or landing systems enabling CAT II, CAT IIIA or CAT IIIB operations. With a minimum operational network of conventional navigation equipment.

National regulation

The ***"Regeling boorduitrusting"***[8], in Dutch, is national regulation that requires aircraft flying in The Netherlands FIR above FL100 to be RNAV 5 equipped, and aircraft flying into Amsterdam Airport Schiphol and Lelystad Airport to be RNAV 1 equipped. These regulations are implemented and published in the Aeronautical Information Publication (AIP) of The Netherlands.

2.3 Strategic goals

The strategic goals for PBN are based on the general goals for aviation by the Dutch Government, as indicated in the 'Luchtvaartnota'[9]. Furthermore, following from extensive stakeholder consultation within the Netherlands, stakeholder challenges and benefits have been identified. These challenges and benefits are presented in greater detail in chapter 3.

The goals of the PBN developments for the Netherlands FIR in the 2020-2030 timeframe can be found in Table 1.

Table 1 Strategic goals for PBN

Symbol	Description
	Safe traffic flows
	Reduce environmental impact & enable Continuous Climb and Continuous Descent Operations (CCOs/CDOs): **below 6000 ft:** minimise noise impact (concentration of noise along fixed routes) **above 6000 ft:** minimise emissions (shortest possible routes)
	Improved predictability of flight tracks (implementation of fixed routes for arrivals and departures)
	Improved airport and heliport accessibility (IFR access)

The symbols used for each of the five strategic goals will be used throughout this document in order to highlight the relationship between specific PBN elements and the respective goal to which they contribute.

2.4 Elements for the roadmap

In order to achieve the strategic goals mentioned in section 2.3 and comply with the regulations mentioned in section 2.2, several PBN elements are available. These elements are categorised in the ones relevant for ATS routes, for arrivals (STARs) and departures (SIDs), for approaches (APCH) and for helicopter operations (Point in Space – PinS – procedures and RNP approaches/departures/routes). Note that for the approaches, all procedures after the initial approach fix are considered. This, therefore, also includes the current (night) transitions, which are included with the RNP APCH and RNP AR APCH (Authorisation Required) concepts in this document.

Figure 4 below illustrates this categorisation. Note that taxi and other ground operations are not considered within the scope of this Roadmap.

Figure 4 Categories for the PBN roadmap elements

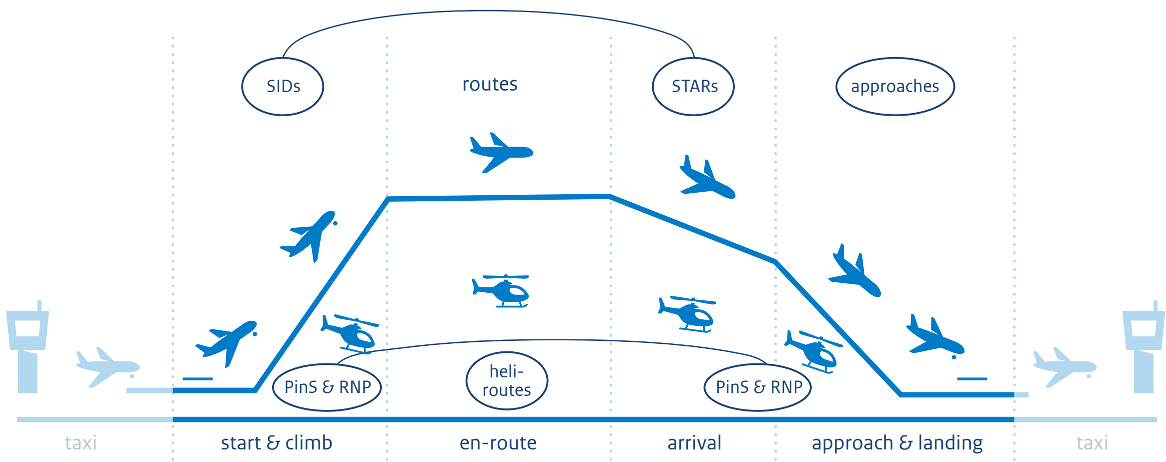


Table 2 provides an overview of all PBN elements used in the Roadmap. The icons in the table denote the main purpose of that specific element in relation to the strategic goals as outlined in section 2.3. Note that the absence of an icon for a specific PBN element does not mean that it can't contribute to that specific goal, just that it's not its main driver.

The PBN elements summarised in Table 2 are a combination of navigation specifications (RNAV 1, RNP 1, RNP APCH, RNP AR APCH) of navigation applications optimised for environmental impact reduction and supporting concepts (RNP to xLS, RNAV-visual and Established on RNP-EoR). These combinations enable gradual implementation of PBN, tailored for the specific situation of each airport. By providing benefits for airports and airspace users, the transition towards PBN is stimulated.

Table 2 Overview of PBN elements

	Safe traffic flows	Noise abatement	Reduced emissions	Predictable flight tracks	Airport accessibility
SIDs ad STARs					
RNAV 1 SIDs/STARs	●				●
RNP 1 SIDs/STARs	●			●	
RNAV 1 SIDs/STARs		●	●		
RNP 1 SIDs/STARs + RF-legs		●	●	●	
Approaches					
RNP APCH - straight-in	●				●
RNP APCH + RF-legs		●	●	●	
RNP AR APCH + RNAV-visual		●	●	●	
RNP APCH + RNP to xLS				●	●
RNP AR APCH + EoR	●			●	●
Helicopter operations					
RNP 0.3 route sructure	●		●		●
PinS / COPTER RNP procedures	●	●	●	●	●

- Safe traffic flows
- Noise abatement
- Reduced emissions
- Predictable flight tracks
- Airport accessibility

ATS routes

For (fixed wing) ATS routes, the PBN specification “RNAV 5” is applicable. Currently, all ATS routes in the Netherlands are already RNAV 5 compliant. No developments are foreseen within the time scope of the roadmap. Other navigation specifications, such as RNAV 2 or RNAV 1, are currently not used for ATS routes within European airspace. There are no Pan-European plans to transition towards these more accurate specifications. This is due to the foreseen limited operational benefits and also due to the imminent transition towards the Free Route Airspace (FRA) concept in the upper airspace. The FRA concept is based on direct connections between entry and exit points of predetermined airspace volumes, so no (PBN) routes are foreseen. Minimum spacing between traffic flows, and thus capacity, is determined by radar separation criteria and not by PBN navigation accuracy.

SIDs and STARs

For SIDs and STARs, there are two relevant navigation specifications: ***RNP 1*** and ***RNAV 1***. Four PBN elements for SIDs/STARs are defined based on these specifications and desired developments with respect to environmental impact reduction.

RNAV 1 SIDs/STARs

RNAV 1 is the default for all new SIDs and STARs. However, until recently, most RNAV 1 SIDs/STARs have been developed as "overlays" of conventional SIDs/STARs, following the same, non-optimal, tracks of conventional routes. The PBN IR[7] mandates the implementation of RNAV 1 for all IFR airports. With new RNAV 1 SIDs and STARs, airports can be accessed under IFR conditions and the routes designed independently of conventional navigation aids.

RNP 1 SIDs/STARs

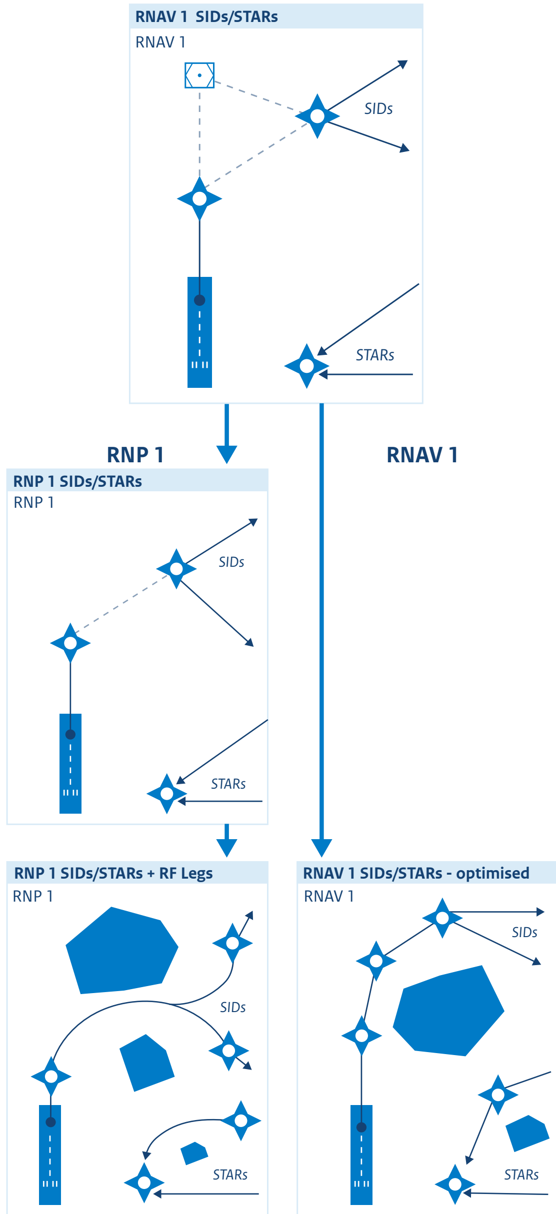
Transition from the current RNAV 1 SIDs/STARs to RNP 1 SIDs/STARs at Schiphol Airport. This transition can be done with no impact for the routes of the SIDs and STARs. However, the navigation capabilities of the airspace users will be more stringent and include integrity monitoring, thereby improving safety and better ensuring track adherence.

RNAV 1 SIDs/STARs - optimised

A logical development for RNAV SIDs/STARs is to make full use of the design flexibility and abandon the "overlay" principle for existing RNAV SIDs/STARs. This is expected to result in noise optimal SIDs/STARs. Note that in situations where there are currently no (RNAV) SIDs/STARs, the first PBN element (RNAV 1 SIDs/STARs) may be skipped in favor of this step.

RNP 1 SIDs/STARs + RF-legs

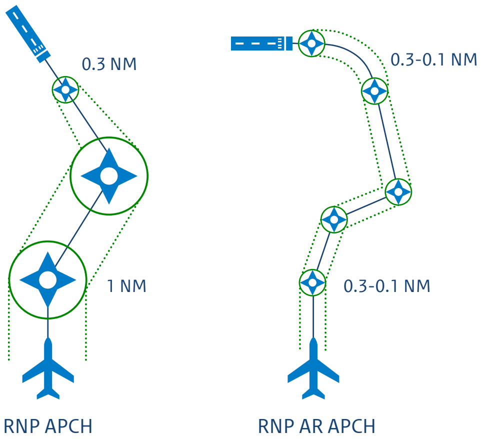
With the RNP 1 specification, the possibility to make use of RF-legs is introduced. RF-legs provide improved track adherence during turns, thus concentrating the noise along the defined nominal track. At the airports where RNP SIDs/STARs are foreseen, this is a logical development to further exploit the benefits of RNP for environmental impact reduction.



Approaches

For the approaches, there are two main navigation specifications: ***RNP APCH*** and ***RNP AR APCH***. These form the basis upon which the PBN Approach elements for this Roadmap have been built.

Figure 5 RNP APCH versus RNP AR APCH



In addition to the two navigation specifications, three 'supporting' concepts are considered in the roadmap. By combining the two navigation specifications with these concepts, an increased use of the relevant PBN element is enabled:

- ***RNP to xLS***: allows for the use of RNP routings to ILS (especially for low visibility operations)
- ***RNAV visual:*** enables non-RNP AR APCH compliant operators to fly the RNP AR APCH routings (under visual conditions)
- ***Established on RNP (EoR):*** enables the use of independent parallel approaches (RNP AR APCH required)

Note that the supporting concepts mentioned above are relatively new, and there are still uncertainties in the technical and operational aspects. Their feasibility is therefore not guaranteed (within the timeframe of the Roadmap). Additional studies will be required to determine the costs & benefits associated with their implementation.

By combining the navigation specifications with the supporting concepts, five PBN elements are defined. These are defined in such a way that they support a transition towards more noise optimal routes and at the same time enable for their use in high(er) traffic density situations. To be able handle this higher traffic density, a change in operational concept, including advanced system support, is foreseen to be necessary. Please consult section 5.2 for more details.

Ground Based Augmentation System (GBAS)

Although GBAS is not a PBN component, it is considered the most promising concept for future (2030+) replacement of ILS Cat II/III operations. In order to prepare for the transition towards GBAS Landing System (GLS) approaches, it is important to start GBAS trials as soon as possible, so within the 2020-2030 time-scope of the Roadmap. Implementation of GLS approaches will depend on the results of these trials and cost-benefit analysis outcomes. Realisation is not foreseen before 2030.

RNP APCH - straight-in

Similar to SIDs/STARs, RNP approaches have initially been developed as "overlays" of the current conventional approaches. This step ensures compliance with the PBN IR, but has only limited operational and environmental benefits. In situations where the ILS is not available (e.g. due to maintenance or repair), a precision approach is available (instead of a non-precision approach).

It is also important to note that Advanced RNP (A-RNP) has the potential to provide the similar environmental impact reduction benefits as RNP AR APCH navigation specification whilst keeping aircraft and operator requirements at (more) acceptable levels. Details of the A-RNP specifications are unknown at this moment. It is therefore not selected as a PBN element for this roadmap. Nevertheless, A-RNP may also be used instead of RNP AR APCH and/or RNP APCH, to enable more advanced use of RNP techniques. More information about the potential use and specifications of A-RNP will be included in the next release of the PBN Manual[10], expected in the first half of 2021.

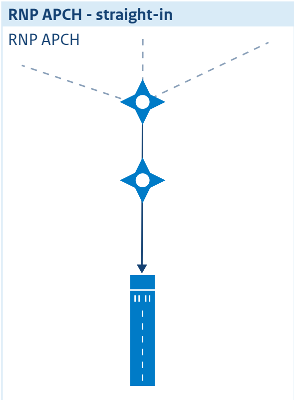
The RNP APCH straight-in can also be used to enable IFR access to (new) airports. However, if traffic densities are low, using the next PBN element, with RF-legs, is preferred.

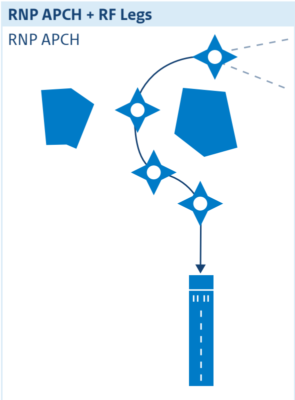
RNP APCH + RF-legs

The RNP APCH specification can be used to define noise optimal approaches. Where necessary and useful, RF-legs may be used to improve track adherence during turns. However, it is important to note that within the RNP APCH specification, RF-legs may only be used before the final approach. For use of RF-legs closer to the runway, RNP AR APCH is necessary.

Although these type of approaches are optimal in terms of noise abatement, the track-miles, and thus also emissions / fuel consumption, may be higher compared to a 'regular' approach. Noise optimal paths sometimes need longer routes to avoid populated areas; for example the Schiphol night transitions.

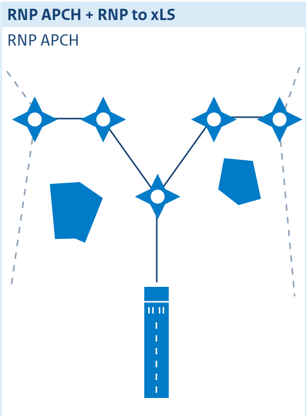
PBN elements ***RNP APCH 'straight-in'*** and with ***RF-legs*** are currently being implemented at Schiphol airport. An example of the 'straight-in' procedure is the RNP approach to RWY 06 (AD 2.EHAM-IAC-06.3). An example of 'RF-legs' procedure is the RNP night approach to RWY 18C - NIRSI 1D (AD 2.EHAM-IAC-18C.3). Vertical paths of the procedures mentioned above are shown in Appendix I.





RNP APCH + RNP to xLS

In most cases, RNP 'straight in' approaches can easily be transformed into RNP approaches with a 'base-leg to final' (Y-type) segment. An example of this type of approach is already implemented at Schiphol airport: the RNP APCH for RWY22 (AD 2.EHAM-IAC-22.3). The advantage of such a base-leg segment, with a pronounceable five letter name code waypoint at the beginning, is that air traffic controllers can vector directly to this waypoint. This results in a common segment for this part of the approach, increasing the predictability of the flight paths.



Due to the limited length of the common segment, these approaches can also be used during medium-to-high traffic situations, provided that operational concepts are also developed (see section 5.2). As such, this PBN element, can contribute to make the transition towards laterally and vertically optimised (partially) fixed routes. This is an important goal for the airspace redesign programme of The Netherlands.

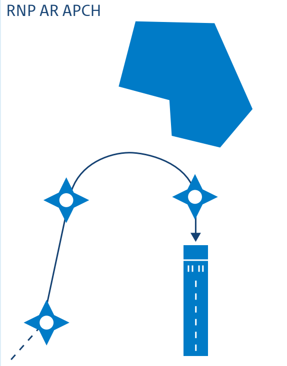
To increase the possibilities to use this element under low visibility conditions, it is proposed to combine it with the RNP to xLS concept. This is expected to result in routings which are very predictable (from the base-leg segment) and can be used during most conditions.

RNP AR APCH + RNAV-visual

Using the RNP AR APCH specification, some of the drawbacks of RNP APCH elements may be mitigated, especially by enabling (RF) turns closer to the runway. RNP AR APCH gives the flight procedure designers additional freedom in the location of the waypoints and routes. This is expected to result in less track miles and maybe also additional noise benefits. However, current RNP AR APCH capability-rates are low: around 10% for European flights and around 15% for Schiphol flights[11]. These rates are not expected to increase to more than 60% in the next 10 years.

RNP AR APCH + RNAV-visual

RNP AR APCH



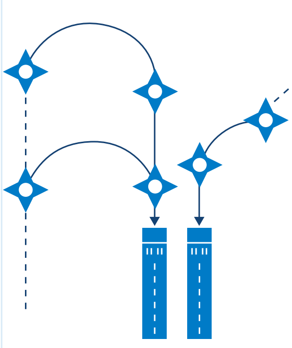
In order to improve the usability of the RNP AR APCH routes, it is proposed to combine them with ‘overlays’ of RNAV-visual routes. These RNAV-visuals can be used roughly 75%[12] of the time, during visual methodological conditions, and by most of the RNP APCH capable traffic, thereby increasing the potential operational use significantly. Note however that the feasibility of this combination will have to be confirmed by more detailed cost-benefit analysis. Depending on the outcome of this analysis, implementing RNP AR APCH without the RNAV-visual component may be considered.

RNP AR APCH + EoR

The next step in the development of RNP AR approaches would be to increase their use during medium-high traffic situations. The feasibility of this step largely depends on the RNP AR APCH capabilities of the operators. The “Established on RNP” (EoR), which has been implemented at Calgary and Denver airports enables independent approaches to parallel runways, together with vertically and laterally optimised flight paths. This combination is expected to improve the chances of a positive cost-benefit balance for RNP AR APCH procedures and operator capabilities.

RNP AR APCH + EoR

RNP AR APCH

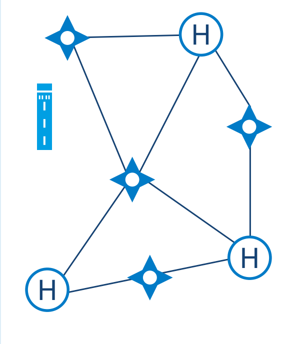


Helicopter operations

For helicopter operations, the ***RNP 0.3*** navigation specification is the basis for the proposed PBN elements. With this specification, it is proposed to develop a low-level helicopter route structure and helicopter departures and approaches: PinS or COPTER RNP procedures.

RNP 0.3 route structure

RNP 0.3



RNP 0.3 low-level route structure

An RNP 0.3 route structure can connect the different locations from which airport operations take place. This improves the safety and continuity of the operations, especially under low visibility conditions.

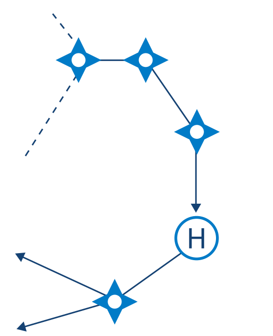
PinS / COPTER RNP procedures

COPTER RNP procedures (SIDs, arrivals and approaches) can be used to develop PBN procedures to IFR airports. PinS procedures can be used at helipads or locations without IFR facilities, such as at hospital landing pads or offshore locations. In some situations, integration with current Airborne Radar Approach (ARA) procedures may be necessary.

Compared to COPTER RNP procedures, PinS offer more freedom to design the routes. For example, the final approach track need not be aligned with the last part of the landing path. The IFR part of the PinS procedure is followed by either “proceed VFR” or “proceed visually”. “Proceed visually” may offer lower approach minima and obstacle protection during this part of the approach, but requires obstacle clearance surfaces to ensure that no new obstacles in the approach areas appear.

PinS / COPTER RNP procedures

RNP 0.3



3 PBN benefits & challenges

The most important PBN benefits are defined in the following areas: safety & predictability, environment, efficiency, accessibility and economy. The challenges are mainly focused on the equipment needed, harmonisation, redundancy, regulation and the community response. This chapter elaborates upon these areas.

3.1 Benefits

Improves safety & predictability

The most important benefit associated with the use of PBN is the enhanced safety of operations. From the conducted interviews with the stakeholders, several factors were identified as being important to this benefit. These factors are divided over:

- Strategic separation & deconfliction
- More accurate and predictable navigation performance
- Possibilities for U-space / RPAS integrations

Strategic separation & deconfliction

The Dutch Airspace is a dense airspace in which capacity for all airspace-users needs to be enabled while safety is guaranteed. One of the elements of Dutch Airspace Redesign program[13] is strategic separation and deconfliction of air traffic. This could benefit from the enhanced accuracy of PBN, and airspace infringements can be better avoided. Traffic flows could be better segregated between arriving, departing and transit traffic. For example, with the use of 3D-corridors and fixed routes.

An additional step in improving safety by means of strategic separation and deconfliction is the mandated use of RNP 1 in the Schiphol TMA, due to the on-board navigation performance monitoring and alerting by the PBN systems. In this way, by continuously monitoring the performance and the capability of alerting the pilot if the aircraft performance falls below that which is required, the accuracy is actively assured.

Also safety of helicopter operations can be improved with the development of PBN IFR approaches to airports currently having non-precision approaches or only VFR procedures. Helicopter RNP0.3 routes in combination with PinS departures and approaches will allow helicopter operators to fly large parts of their flights IFR instead of VFR below cloud in marginal conditions.

More accurate and predictable navigation performance

A more accurate and predictable navigation performance will lead to safer operations for all airspace users. Also, there will be less need of air traffic vectoring with the use of 3D-corridors and fixed routes, which potentially also reduces the workload of air traffic controllers as less tactical intervention is needed. The risk on communication errors between the airspace users and air traffic controllers is expected to be reduced. The development of IFR approaches based on PBN could improve the safety of current non-precision operations and will facilitate access to regional and local, currently non-IFR, airports. Back-up procedures for precision approaches at major airports can possibly have a higher level of safety and lower approach minima. This requires further research on the classification of airspace, safety and eligibility.

Possibilities for U-space / Remotely Piloted Aircraft Systems (RPAS) integration

Further development with RPAS integration in the current airspace can be made possible with PBN. For example, non-RPAS aircraft will be able to follow pre-defined routes in more accurate and predictable ways, thus resulting in more efficient airspace usage. This potentially leads to a reduction in the volume of controlled airspace. This could, therefore, enable an increase in airspace capacity which creates more possibilities for other airspace users (like RPAS and GA).

Reduces environmental impact

Airports in the Netherlands are limited in their operation mainly due to their impact on the environment and communities. ***Noise abatement and lowering of emissions is seen as an important purpose of the implementation of PBN***. In the 'Luchtvaartnota'[9], noise abatement below 6000 ft altitude has the main priority. Above this altitude, reduced emissions are the main priority. This is made possible with increased route predictability, concentration of flight tracks and more efficient flight procedures (CCO, CDO, Curved Approaches and 3D-routes). The ability of PBN to provide shorter route length or vertical windows with the use of Continuous Climb Operations or Continuous Descent Operations allows for more fuel efficient profiles and therefore lowering noise and emissions.

Aviation noise in the Netherlands has a big impact on the society. This issue is related to the densely populated areas. More accurate and predictable flight tracks allow avoidance of noise sensitive areas. To reach the highest accuracy and predictability of flight tracks, the usage of Radius-to-fix turns can be key. Lowering noise production over densely populated areas will decrease the number of noise affected residents. This is not only the case for the departures, but fixed approaches with RF-legs would also enable a further reduction in noise affected residents. For example, a new fixed approach procedure at RWY 18C at Schiphol, which avoids densely populated areas with the use of RF-legs.

In the future, new applications from SESAR concepts could enable Increased Glide Slopes (IGS), Second Runway Aiming Point (SRAP) and Advanced RNP (A-RNP), not specifically focused on terrain and obstacle clearance like RNP AR, could enable a further noise nuisance reduction.

Improved efficiency and accessibility

PBN can be used to better manage and define shorter, more efficient routing in complex Dutch airspace. One of the greatest advantages of PBN is that flight routes and procedures no longer directly have to pass ground-based Navigation Aids (NAVAIDs). Therefore routes can be designed with more flexibility, where they give flight efficiency benefits and avoid conflicts between traffic flows. PBN also enables the development of fixed approach routes to Schiphol and other National airports. The change from RNAV 1 to RNP 1 in the Schiphol TMA which also improves parallel runway and converging operations. The use of 3D routes may increase capacity due to a more efficient use of the airspace.

The development of PBN IFR procedures (departure and approach) for regional airports in (current) uncontrolled airspace results in an increased accessibility for Dutch and international aviation. Heliports and designated landing areas can be equipped with PBN PinS approaches to facilitate operations for Search And Rescue (SAR) and medical assistance in all weather conditions.

Reduces economic costs

The replacement of conventional NPAs by PBN procedures enables decommissioning of conventional NAVAIDS such as VORs and NDBs. This leads to cost reductions on the longer term for users due to eliminating costs for procurement and maintenance associated with this (upkeep, upgrades, airspace usage charges), which are directly incorporated in the ATC charges.

3.2 Challenges

Equipment and capabilities

Due to different fleet standards, airlines are not always capable of flying certain PBN procedures. For this reason, new standards are difficult to implement by retrofitting older aircraft, but also due to new maintenance procedures of aircraft. This is not only relevant to users, but there is also a change to the daily operation of ANSPs.

The PBN knowledge of the organisations workforce is a prerequisite for successful implementation. In addition, the work of air traffic controllers changes from traditional active control techniques to managing traffic on fixed routings based on more accurate and predictable flight paths. This could lead to the need of different skills, training requirements and advanced decision support tools and systems. Management of the skills and changes from a human performance perspective is essential, both from airspace users and service provider perspective. In addition, the integration of advanced technology and system intelligence needs to be carefully chosen in such a way that both human performance and technology strengthen each other in the management of a safe, efficient and expeditious flow of air traffic.

Regulations and funding

By several stakeholders challenges resulting from mandated regulations and the needed funding for implementation of PBN were mentioned. First of all the challenge of implementing the requirements from the EU PBN implementing rule in the Dutch airspace. It is feared that there are insufficient resources and funding to implement the new PBN Procedures. A funding scheme to support PBN implementation is highly appreciated by airspace users, especially for the initial compliance to PBN regulations.

Communities

Due to the accuracy and predictability of PBN flight procedures, flight track concentrations will be increased. Although this is seen as a benefit by lowering the amount of people affected by aircraft noise, some communities still reside beneath the PBN flight routes. Therefore, it is important to inform communities about the implementation of new procedures (for example at Schiphol 18C or Microklimaat RWY06 at Rotterdam) to manage their expectations. The government is working on updating the airspace change procedure to increase participation requirements and better ensure communities are properly informed. The only way to create trust with communities is with clear communication. It will not only be a matter of communication there will also be discussion about concentration versus spreading of noise. Specific mitigations to the impact of concentration can be considered for example alternation and multiple route options.

Redundancy and validation

The shift from ground NAVAIDs to GNSS leads to a dependency due to the vulnerability of the GNSS signals and coverage. GNSS systems are vulnerable to disruptions due to solar eruptions, jamming and spoofing. Unlike current NAVAIDS, this could affect navigation capabilities in a larger area. It is important to develop redundancy plans in case of GNSS failures. An important part of the current fall back procedures is the Minimum Operating Network (MON) as VOR, DME and ILS systems are and will be in operation in the future. Further development of multi-constellation satellite systems could be an additional solution to increase redundancy.

The development of implementing more PBN flight procedures leads to more dependence on data. So the use of validated data is of greater importance. The data and the process that leads to validated data needs to be accurate and standardised.

Harmonisation and commitment

An important step, according to the stakeholders in the development of PBN, is the harmonisation of a European/World standard. The differences in standards (like LPV/GLS/RNP2/A-RNP) make it difficult to equip, invest and develop PBN. Furthermore, the role of Galileo in PBN is unclear due to the fact that Galileo is not yet part of the ICAO Annex 10 SARPs. To reach this, a better cooperation and an improvement in conversation between European authorities/ANSPs/manufacturers is needed. Also, more cooperation and alignment between Airlines, ANSP, and communities helps to create a support base for the implementation of PBN procedures. In order to embrace a new standard, a realistic transition period with a specific timeline is important.

There are challenges mentioned about the development of PinS and low-level RNP 0.3 NM routes in class E, F and G airspace in relation to VFR operations. This should be carefully considered and evaluated with respect to safety impact before implementation. Possible solutions to mitigate these issues are radio and transponder mandatory zones and publication of procedures on VFR charts.

4 PBN developments for The Netherlands FIR

Foto: Media Centrum Defensie

4.1 Introduction

The PBN developments for The Netherlands FIR in 2020-2030 are based on two pillars: regulations & operational goals. Please consult sections 2.2 and 2.3 respectively for more information on these pillars.

Given that the regulations are Airport and Runway-Type based, the PBN Roadmap categorises the PBN Development for The Netherlands FIR by airport type. EU Commission Regulation No 139/2014[14], which states that the local airports are responsible for the provision of air navigation services including the design and maintenance of the flight procedures, supports this choice. This chapter lists the various airports and/or airport types applicable to a certain PBN Development. Under each airport or airport type, the PBN developments based on the regulations and operational goals are listed.

The airports are categorised based on their *current* status. However, airports may transfer to another airport category by up- or downgrading their capabilities. This is especially true for the Regional IFR and non-IFR airports. At the point of writing, it is known that some non-IFR airports have ambitions to upgrade to IFR airports by using (only) PBN procedures, which is one of the strengths of PBN.

Each of the PBN developments listed as part of the operational goals in this chapter is dependent on an individual assessment by local stakeholders. Operators, airports, ANSPs and government will need to align their ambitions/requirements and assess the feasibility of the individual PBN developments in detail. Based on this assessment, the implementation plan (with final timelines) for the individual PBN development can be defined. The sequence of the listed PBN developments in this chapter gives an indication on the order of developments. A specific development time is not indicated as this depends on the outcome of the previously mentioned assessment.

4.2 Amsterdam Airport Schiphol (EHAM)

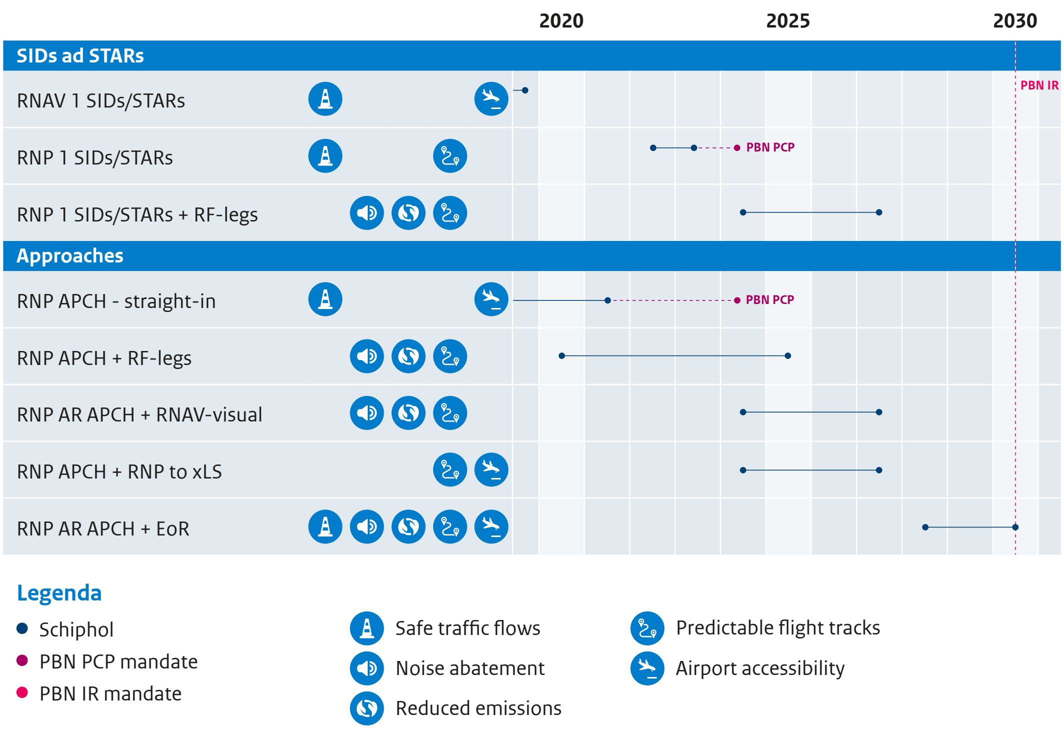
Amsterdam Airport Schiphol is the mainport of The Netherlands . As mainport, Schiphol has a responsibility to the community in terms of environmentally friendly operations. ***PBN developments can support environmentally friendly operations, in combination with other technological and procedural measures.*** PBN will enable the step towards fixed, deconflicted, arrival & departure routes, combined with CDOs/CCOs.

The PBN developments foreseen for Amsterdam Airport Schiphol, based on the regulations, for the 2020-2030 period are as follows:

- Develop 'Straight-in' RNP-APCH (LNAV, LNAV/VNAV, LPV) (PBN IR requirements, 3 Dec 2020 / 25 Jan 2024).

The PBN developments foreseen for Amsterdam Airport Schiphol, based on the operational goals, for the 2020-2030 period are shown in Figure 6 below. Note that the PBN elements "RNP 1 SIDs/STARs + RF-legs" and "RNP APCH + RNP to xLS" are related to the airspace redesign program of The Netherlands and contribute to its goal to achieve fixed, optimal, routings for in- and outbounds.

Figure 6 Foreseen PBN elements for Amsterdam Airport Schiphol



Amsterdam Airport Schiphol needs to change from RNAV 1 to RNP 1 by regulations. With this, it will become more acceptable to use RF-legs as the RNP 1 specification includes RF-legs as optional elements. Most aircraft flying to Schiphol will be able to fly the RF-legs. Hence, SIDs and STARs can be further optimized using RF-legs for noise abatement. Given the discussions about environmental issues versus the number of flights at especially Amsterdam Airport Schiphol, further optimised SIDs and STARs for noise are welcome, RF-legs can provide this option.

Amsterdam Airport Schiphol has multiple runways. Some of the PBN developments will be applicable to all runways (e.g. RNP APCH - Straight In and RNP1 SIDs/STARs). Depending on the more detailed stakeholder assessment, most other PBN developments will be implemented for a limited amount of runways:

- The "RNP AR APCH + EoR" is mainly interesting for the parallel runways, so will be applicable for the combination 36C/36R and 18R/18C only.
- The "RNP AR APCH + RNAV Visual - noise optimal, low traffic" application might be implemented for the preferred runways for night operations only. AR capable operators see advantages of these approaches to reduce track miles (and thereby emissions), while at the same time avoiding built-up areas (for noise). In order to allow also non-AR capable operators to fly these approaches, the RNAV Visual procedure is suggested, following the same geographic route, under different rules and minima.

4.3 National Airports, part of Schiphol TMA (EHRD, EHLE)

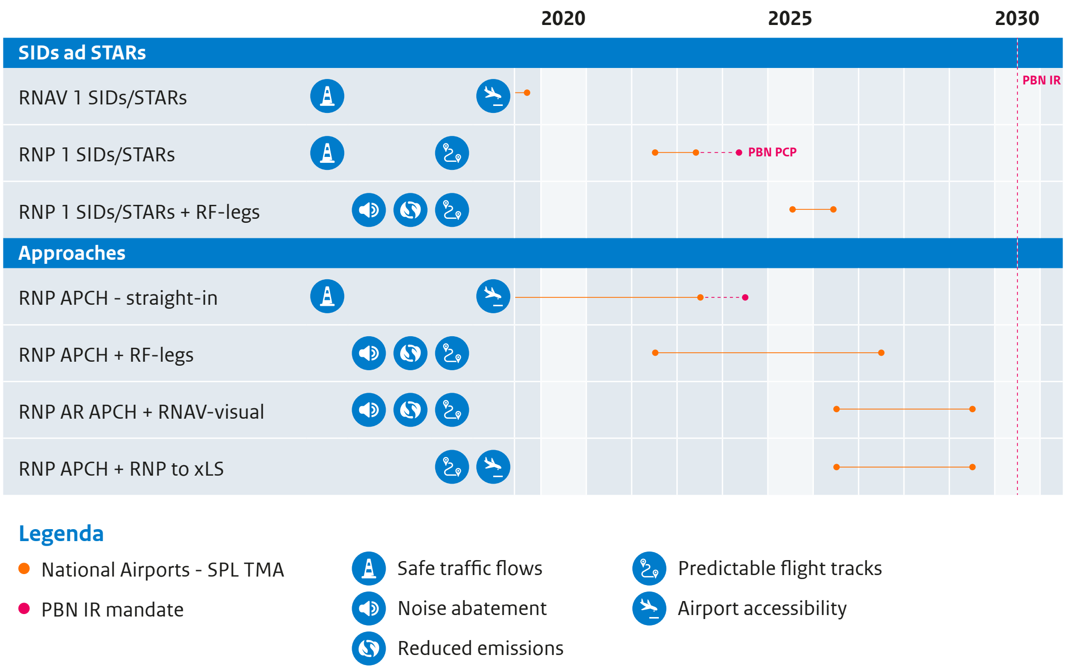
National airports Rotterdam The Hague Airport (EHRD) and Lelystad Airport (EHLE) have a similar responsibility as Schiphol to the community in terms of environmentally friendly operations. Traffic flows from and to EHLE and EHRD also use a part of the Schiphol TMA. ***To create uniformity and therefore safety, PBN developments for these airports will be aligned with the PBN developments for Schiphol, although shifted in time***.

The PBN developments foreseen for the National Airports which are part of the Schiphol TMA (EHRD, EHLE), based on the regulations, for the 2020-2030 period are as follows:

- Develop 'Straight-in' RNP-APCH (LNAV, LNAV/VNAV, LPV) (PBN IR requirements, 3 Dec 2020 / 25 Jan 2024).

The PBN developments foreseen for Rotterdam The Hague Airport and Lelystad Airport, based on the operational goals, for the 2020-2030 period are shown in Figure 7 below.

Figure 7 Foreseen PBN elements for Rotterdam The Hague and Lelystad Airports



When compared to Amsterdam Airport Schiphol, the PBN developments for Rotterdam The Hague Airport and Lelystad Airport are shifted to a later date in time. The idea is to focus on Amsterdam Airport Schiphol with PBN developments, gain experience and transfer these developments to Rotterdam The Hague Airport and Lelystad Airport, where and when applicable.

4.4 National airports, not part of Schiphol TMA (EHBK, EHEH, EHGG)

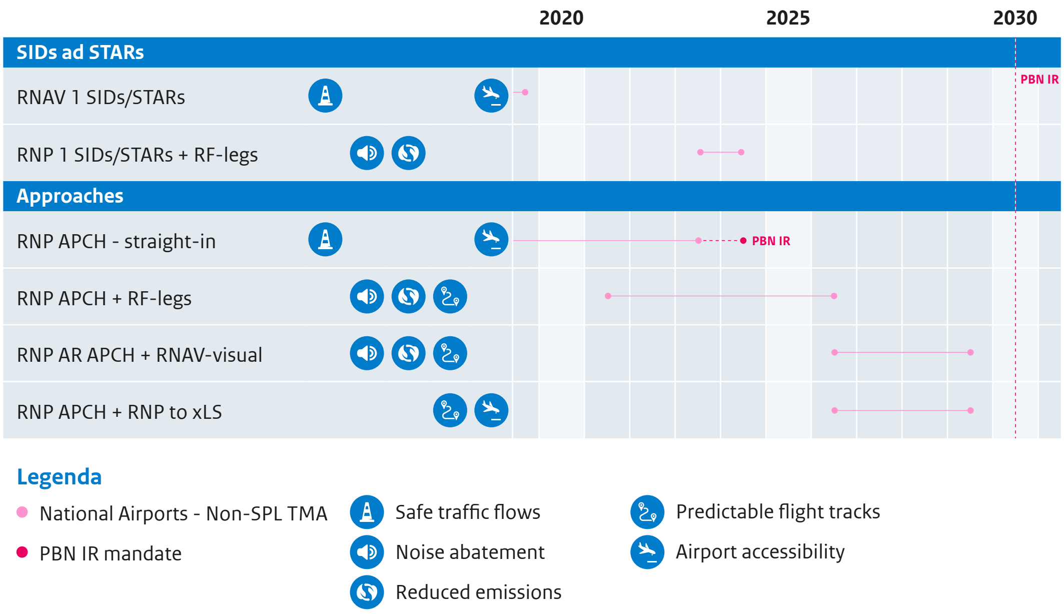
Maastricht Aachen Airport (EHBK), Military Airport Eindhoven (EHEH) and Groningen Airport Eelde (EHGG) are national airports but are not part of the Schiphol TMA. Hence, PBN requirements on Schiphol Airport are not directly applicable to these airports. Nevertheless, ***PBN elements provide benefits for these airports in terms of improved operational continuity and reduced environmental impact***.

The PBN developments foreseen for the National Airports which are not part of the Schiphol TMA (EHBK, EHEH, EHGG), based on the regulations, for the 2020-2030 period are as follows:

- Develop 'Straight-in' RNP-APCH (PBN IR requirements, 3 Dec 2020 / 25 Jan 2024).

The PBN developments foreseen for Maastricht Aachen Airport (EHBK), Military Airport Eindhoven (EHEH)) and Groningen Airport Eelde (EHGG), based on the operational goals, for the 2020-2030 period are shown in Figure 8 below.

Figure 8 Foreseen PBN elements for Maastricht Aachen, Eindhoven and Groningen Eelde Airports



When compared to the airports which are part of the Schiphol TMA, the main difference is that the airports not part of the Schiphol TMA will not implement RNP 1 SIDs/STARs in the timeframe of this PBN Roadmap. These airports will maintain RNAV 1 SIDs/STARs, and consequently will also not use RF-legs in the SIDs and STARs.

The PBN Approach Developments for the national airports and not part of the Schiphol TMA are shifted to a later date in time, compared to the Schiphol Airport PBN developments and also compared to the national airports part of the Schiphol TMA.

Military Airport Eindhoven (EHEH) is a special airport in this context, since Eindhoven is a military airport with civil co-use. This means that the airport authority is part of the Ministry of Defense and the ANSP is the Minister of Defense. The local stakeholder assessment, as previously mentioned, for PBN developments on Military Airport Eindhoven might for this reason take a different track than the civil airports Maastricht Aachen Airport and Groningen Airport Eelde. In essence however, the PBN operational goals for Military Airport Eindhoven will be similar to Maastricht Aachen Airport and Groningen Airport Eelde.

4.5 Regional IFR airports (EHBD, EHKD, EHTE)

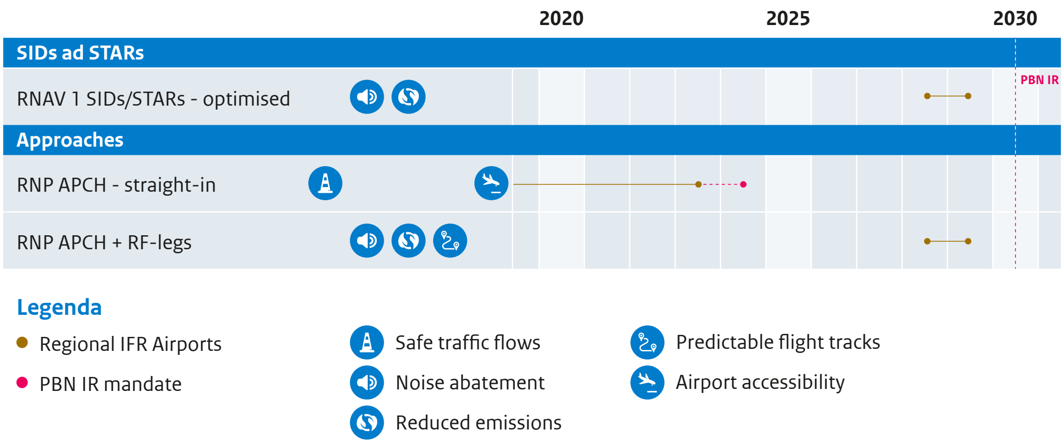
Kempen Airport (EHBD), Military Airport De Kooy (EHKD) and International Airport Teuge (EHTE) are regional airports. However, these airports have instrument runways and published IFR procedures. ***PBN elements provide benefits for these airports in terms of improved operational continuity and reduced environmental impact***.

The PBN developments foreseen for these regional IFR airports (EHBD, EHKD, EHTE), based on the regulations, for the 2020-2030 period are as follows:

- Develop 'Straight-in' RNP-APCH (PBN IR requirements, 3 Dec 2020 / 25 Jan 2024).

The PBN developments foreseen for Kempen Airport (EHBD), Military Airport De Kooy (EHKD) and International Airport Teuge (EHTE), based on the operational goals, for the 2020-2030 period are shown in Figure 9 below.

Figure 9 Foreseen PBN elements for Kempen, Den Helder and International Airport Teuge airports



Military Airport De Kooy is a special airport in this context, since Military Airport De Kooy is a military airport with civil co-use. This means that the airport authority is part of the Ministry of Defense and the ANSP is the Minister of Defense. The local stakeholder assessment, as previously mentioned, for PBN developments at Military Airport De Kooy might for this reason take a different track than the civil airports Kempen Airport and International Airport Teuge. In essence however, the PBN operational goals for Military Airport De Kooy will be similar to Kempen Airport and International Airport Teuge.

Military Airport De Kooy is a controlled airport, unlike Kempen Airport and International Airport Teuge. Compared to Military Airport De Kooy, Kempen Airport and International Airport Teuge will have an extra challenge to separate IFR traffic using PBN procedures and VFR traffic not using PBN procedures, while not having an air traffic control service.

4.6 Regional non-IFR airports (EHTX, EHHV, EHMZ, EHHO, EHOW, EHDR, EHTW, EHSE, EHAL)

Non-IFR airports in The Netherlands have no requirements from regulations to develop PBN Procedures. However, the operational goals for these airports are clear in the sense that continuity of operations and access to the airports is valued. It is expressed by stakeholders that IFR access to some of these airports is interesting, although PBN developments alone will not be sufficient. Runway lighting, coordination or segregation between VFR and IFR traffic and access to IFR routes nearby are examples of challenges to be solved in parallel to potential PBN developments.

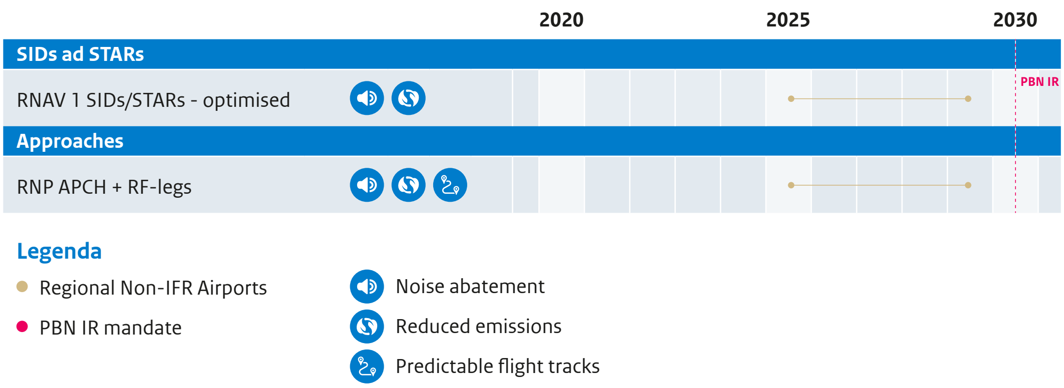
If these airports effectively convert their non-IFR runways into IFR runways by publishing PBN procedures, then they transfer to the Regional IFR group of airports as listed in the previous section. As such, PBN developments (next to other developments and thorough safety analysis) are an interesting means to help this group of non-IFR airports become IFR airports, with minimal investments in navigation aids on the ground.

Especially in this group of airports, the PBN developments are dependent on a local (or regional) assessment and business case. Following EU Commission Regulation No 139/2014[14], the local airports will be responsible for the provision of air navigation services appropriate to the level of traffic and the operating conditions at the aerodrome, including the design and maintenance of the flight procedures.

The sequence of the listed PBN developments for this category gives an indication on the order of developments. A specific development time is not indicated as this depends on the outcome of more detailed investigations.

For this group of airports (non-IFR, non-controlled), based on the operational goals, the potential PBN developments for the 2020-2030 period, to be considered by these airport, are shown in Figure 10 below.

Figure 10 Foreseen PBN elements for non-IFR, non-controlled airports

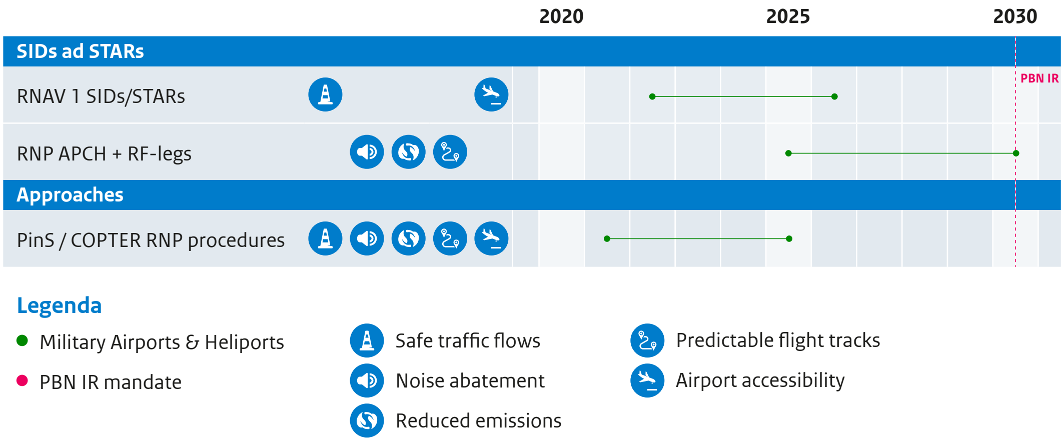


4.7 Military airports (EHLW, EHGR, EHVK, EHWO, EHDL)

Military-only airports in The Netherlands, listed here as separate category, have no requirements from regulations to develop PBN Procedures. In fact, the Military airports are very similar to the National Airports not part of Schiphol TMA (EHBK, EHEH, EHGG). The Military airports have Air Traffic Control (ATC), long and concrete runways, precision IFR procedures (ILS) and non-precision IFR procedures (TACAN). Some military airports already have RNP and COPTER RNP approaches (EHKD and EHLW).

The PBN developments for the Military Airports are highly dependent on the operational goals set by the Dutch Ministry of Defense and link to helicopter operations co-use and potential civil co-use of Military airports. In general, the ambition is to harmonise PBN developments on Military-only Airports in The Netherlands FIR.
Foreseen PBN developments for the Military Airports, based on the operational goals, for the 2020-2030 period are shown in Figure 11 below, including helicopter PBN developments for Military Airports.
PBN elements may provide benefits for these airports in terms of improved operational continuity and reduced environmental impact.

Figure 11 Foreseen PBN elements for the military airports



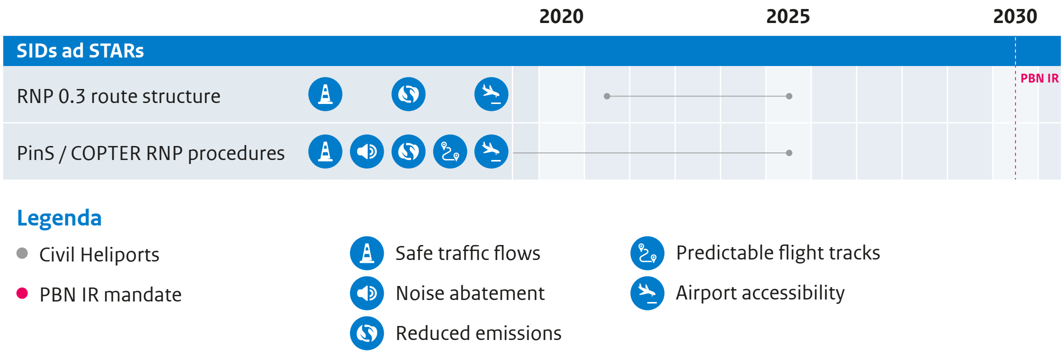
4.8 Heliports and helispots

Heliports and Helispots are currently non-IFR airports, much like the Regional non-IFR airports. However, there is a major difference between the non-IFR airports and the Heliports/Helispots. ***The Heliports/ Helispots have an important role in the Medical Ambulance Service, the Search And Rescue (SAR) and Policing service, which are public services in The Netherlands. Helicopter operations are also essential for North Sea offshore operations***. Therefore, the operational goals for the Heliports/Helispots are driven by the need to be able to continue to provide these services, also at lower weather minima.

Specific PBN developments can assist in improving the helicopter operations in The Netherlands FIR. This involves a RNP 0.3 route structure e.g. connecting to offshore locations, hospitals, airports, strategic locations, rendezvous points. Besides this, PinS (Points in Space) or specific COPTER PBN Procedures to strategic locations (e.g. IFR airports, non-IFR airports, Military Airports) help helicopter operations continue in reduced weather conditions in The Netherlands. Implementation of these PBN procedures is already in progress, for example the COPTER procedures at De Kooy (EHKD), see also Appendix I.

For helicopter operations in The Netherlands FIR, based on the operational goals, the foreseen PBN developments for the 2020-2030 period are shown in Figure 12 below.

Figure 12 Foreseen PBN developments for helicopter operations



Whereas the PBN developments in all previous airport categories are primarily the responsibility of the local stakeholders, the PBN developments for the public interest helicopter operations in The Netherlands FIR shall be organised and initiated by the State, given the public service nature of the operations and the national and non-commercial interest.

5 PBN implementation strategy

5.1 Roadmap overview

Figure 13 provides an overall overview of the PBN Roadmap elements and the timing of PBN developments for all airports, airport types and the helicopter operations: ***The PBN Roadmap***.

5.2 Related developments

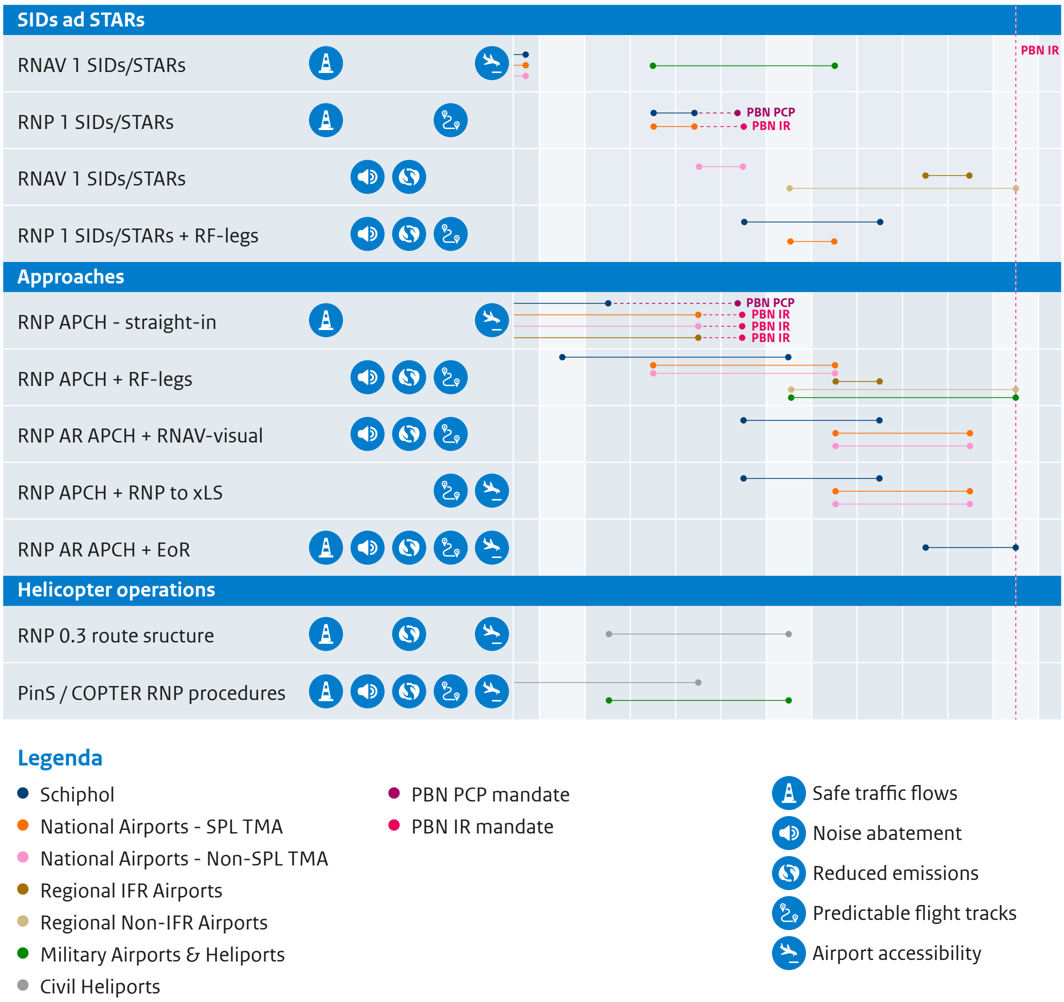
The PBN Roadmap does not stand on itself. PBN is an enabler for many other and wider ATM developments, sharing the same end goals on safety, efficiency and environmental responsibility. This section lists these wider and related ATM aspects, which should be considered in addition to the PBN developments as listed in the PBN Roadmap.

Operational ATM concept changes

PBN is a fundamental enabler for the deployment of the future operational ATM concept[13, 15]. On the other hand, successful implementation of PBN also requires changes in the operational ATM concept. Having the technical solution alone is not sufficient to realise expected safety, efficiency and environmental improvements and goals. Specific enablers for successful implementation of PBN include human performance, procedures, airspace structure, processes between stakeholders and supporting systems/tools. These enablers must be specifically addressed and adapted to support the PBN operational environment and enhance traffic handling in a safe, efficient and environmentally friendly way. This interdependence necessitates synchronised changes and implementation between PBN and wider ATM developments.

The technical implementation of PBN and the use of a combination of PBN and conventional navigation applications at the same time in the same airspace may add operational complexity for ATC and/or the flight-deck, potentially leading to safety risks and capacity impacts. Especially in the transition to integral PBN with different levels of service and navigational capability, it is of crucial importance to consider and manage the complexity of the airspace and operation in The Netherlands.

Figure 13 Overview of PBN developments for The Netherlands (see Appendix II for a larger version of this figure)



Human performance and advanced technology in air traffic control

With the implementation of PBN, traffic handling changes from traditional control techniques to fixed routings and more accurate and predictable paths with PBN. Advanced decision support tools and systems to enable PBN operations in air traffic control are related to blending of traffic streams, separation and sequencing, conformance monitoring and traffic flow management and planning processes. At the same time, the role of human performance remains crucial in providing the operational flexibility and safety that is needed[7, 15]. Therefore, the right balance should be found between the human operator and technology support. The integration of advanced technology and system intelligence needs to be carefully chosen in such a way that both human performance and technology strengthen each other in the management of a safe, efficient and expeditious flow of air traffic.

Safety assessment considerations

In ensuring safety of operations as well as delivering the required navigation performance, operational safety risks related to aircraft system failures and failures in navigation infrastructure should be assessed and mitigated. An example of a potential safety critical aspect is the interaction between IFR and VFR operations in the regional airports. Implementation of PBN components can only take place after verification and approval of these assessments and corresponding mitigation measures by the National Supervisory Authority (NSA) The Netherlands and/or the Dutch Civil Aviation Authority. ICAO's Doc 9997[16] provides guidance for establishing operational approval for PBN operations.

When considering back-up measures for loss or degradation of GNSS infrastructure elements, the guidelines and principles of Eurocontrol's PBN Handbook nr. 6: European GNSS Contingency / Reversion Handbook for PBN Operations[17], should be taken into account. This also provides requirements for the Minimum Operating Network (MON). In addition, resilience of the service for deviations and weather disturbances has to be explicitly taken into account.

Training aspects Air Traffic Controllers and Pilots

ICAO is offering a list of (online) courses covering everything from PBN overview to operational approvals[18]. PBN training packages are available to explain the PBN concept, principles and procedures. Education and training of the involved workforce should be started amply before implementation of PBN.

Implementing PBN also requires (recurrence) training of the pilot community and air traffic control services personnel.[1] Comprehensive training on effectively and operationally using PBN for ATC and pilots is a prerequisite for successful implementation of PBN. Pilots need PBN navigation courses as part of their Instrument Rating, consisting of theory and practical PBN skill-test[21]. This is part of the Instrument Rating requirements as per 25th of August 2020. Approved training organisations need to comply to the PBN requirements[20]. Training of instructors and trainers is required. In addition, PBN requirements in air traffic controller licensing and training are specified[21].

Finally, it is important to note that, to be able to fly RNP AR APCH procedures, additional requirements need to be fulfilled by the operator. These requirements not only relate to aircraft/equipment capabilities, but also crew training aspects and company procedures.

Decommissioning of conventional navigation systems

PBN Development allows for a reduction of the conventional NAVAIDs such as VORs and NDBs. A process has already started in The Netherlands to define the Minimum Operating Network (MON) and consequently remove NAVAIDs from operation.

This process should be carefully planned and executed, informing all stakeholders well in advance and throughout the reduction of the conventional navigation network. Stakeholders will need time to adapt their operations, fleet and training.

The MON is defined in terms of VOR, NDB and DME:

- All current ILS and DME stations will continue to operate in the 2020-2030 timeframe. The DME-network complements the aircraft's GNSS-based navigation capabilities and serves as a back-up in case of loss or degradation of the GNSS infrastructure.
- Most VOR and NDB beacons will be progressively decommissioned:
  - Four VOR radio beacons will be retained as a fallback and resilience network to overcome the case of GNSS outages. These VOR stations are: SPL, RTM, EEL and MAS.
  - All other VOR and NDB (or locator) stations in the Amsterdam FIR are being progressively taken out of service in the 2019-2021 timeframe.

A further reduction of the network after 2030 should be carefully considered and stakeholder involvement on this further reduction is key. Especially ILS CAT I installations, although apparently redundant to PBN applications, serve a purpose in flight operations with limited aircraft capabilities. Furthermore, current RNP (AR) APCH specifications do not cater for navigation capabilities based on a DME-network and can therefore not be used in a GNSS failure/degradation situation.

5.3 General Aviation

General Aviation (GA) is defined by ICAO as "all civil aviation operations other than scheduled air services and non-scheduled air transport operations for remuneration or hire". A lot of activities are part of the General Aviation domain such as balloon, glider and sport aircraft operations.

General Aviation and PBN touch directly when the General Aviation aircraft is IFR and PBN equipped. PBN developments are directly beneficial to PBN capable General Aviation aircraft which are operating according to IFR. These aircraft will have lower minima and improved safety with PBN when compared to current non-precision procedures. At the same time PBN procedures can be published for current non-IFR airports, thereby improving access to these airports, specifically relevant to PBN capable General Aviation IFR traffic.

Non-PBN capable General Aviation IFR aircraft might face more limitations as a result of the PBN developments, since non-precision procedures at airports might be reduced or removed altogether. These aircraft will have to rely on the MON of conventional NAVAIDS at the airports in The Netherlands FIR, or to upgrade to PBN capable equipment.

General Aviation traffic operating according to VFR will not directly benefit from the PBN developments; they are also not directly affected by the PBN developments. However, VFR General Aviation operations might face indirect effects from PBN developments. ***On the positive side, airspace for VFR operations might be increased.*** Since commercial IFR operations will fly more accurately and follow fixed routes with PBN in the future, airspace currently reserved for these operations might be partly opened for VFR operations. ***On the other hand, VFR traffic at these airports might experience limitations due to combined PBN/IFR and VFR operations.*** Especially when currently non-IFR airports are converted into IFR airports using PBN. The same is true with possible interference between low-level RNP 0.3NM PBN helicopter routes and VFR operations.

Meanwhile, satellite navigation, the basic principle enabling PBN operations, is entering VFR operations. Many navigation Apps have been introduced over the past decade for use in VFR operations. These Apps assist the user to stay clear of airspace, weather and sometimes also other traffic. In this way, PBN-enabling technology also has a positive effect on VFR operations.

5.4 Implementation considerations

The ambition and timing of the elements in the roadmap were set in agreement with the PBN Taskforce as well as reflecting the opinions of the sector as a whole. The roadmap provides the basis for the development, implementation and gradual transition to PBN at a national level as well as to ensure interoperability at a European level. Implementation of the PBN Roadmap will be further guided through and detailed in the PBN Transition Plan[5]. ***Close cooperation, coordination between the stakeholders and jointly assessing the (cost-benefit) feasibility is a prerequisite to enable successful implementation of PBN within the proposed timeframe.*** This is specifically important as there will always be trade-offs between benefits, challenges and required investments seen from different perspectives (e.g. user, service provider, airport, general aviation, communities, accommodation of non-equipped State Aircraft).

Increased operational complexity, especially during the transition towards PBN procedures, may limit capacity of the airspace or airport, thereby having a negative effect for the airlines in general. For example, enabling different types of RNP approaches at the same time may provide benefits for the individual airlines but requires considerable investments and poses challenges on service providers in terms of increasing operational complexity. These effects should be carefully considered and discussed among stakeholders before implementing PBN.

Additionally, as can be seen in the related developments that are required for successful implementation of PBN applications, concurrent developments are required for the successful implementation of PBN. ***These consist of operational concept development, airspace structure definition, safety analysis, interoperability analysis as well as development of the required tooling and training of personnel involved.***

The PBN Roadmap provides the direction of PBN in The Netherlands for the period 2020-2030. The process of implementing PBN will uncover the actual benefits and challenges of the particular PBN elements as listed in the PBN Roadmap, per airport category and for all stakeholders involved.

During the process of implementing PBN, actual market circumstances, technical opportunities, potential new regulations and stakeholder abilities and limitations will be taken on board. This will drive the degree in which the ambition set in this PBN Roadmap can be achieved within the proposed timeframe.

5.5 Next steps

The existing PBN Taskforce in The Netherlands will provide oversight over and guidance on PBN developments in The Netherlands in the 2020-2030 timeframe. The Ministry of Infrastructure and Water Management, as chair of the PBN Taskforce, will initiate regular PBN Taskforce meetings with all relevant stakeholders in The Netherlands. The PBN Taskforce will monitor implementation of PBN through the PBN Transition Plan[5]. The PBN Transition Plan details the PBN implementation and is to be considered a "living document" with yearly milestones for the 2020-2030 time period.

The PBN transition plan and (local/regional) PBN implementation plans will need to further specify the required and feasible investments, related developments, resources, costs and lead times implementing PBN in operations.

Abbrevations

ANSP	Air Navigation Service Provider
A-RNP	Advanced RNP
ATC	Air Traffic Control
ATM	Air Traffic Management
ATS	Air Traffic Services
CAT	Category
CCO	Continuous Climb Operations
CDO	Continuous Descent Operations
CFIT	Controlled Flight Into Terrain
CLSK	Commando Luchtstrijdkrachten (Royal Netherlands Air Force)
CNS	Communications, Navigation, Surveillance
COPTER	Helicopter
DME	Distance Measuring Equipment
EASA	European Aviation Safety Agency
EoR	Established on RNP
EU	European Union
EUROCONTROL	European Organisation for the Safety of Air Navigation
FRA	Free Route Airspace
FIR	Flight Information Region
GA	General Aviation
GALILEO	European GNSS
GANP	Global Aviation Navigation Plan
GBAS	Ground-based Augmentation System
GLS GBAS	Landing System
GNSS	Global Navigation Satellite System.
ICAO	International Civil Aviation Organisation
IFR	Instrument Flight Rules
IGS	Increased Glide Slopes
ILS	Instrument Landing System
IR	PBN Implementation Regulation
LNAV	Lateral Navigation
LPV	Localizer Performance with Vertical guidance (APV SBAS I/II)
LVNL	Luchtverkeersleiding Nederland (Air Traffic Control the Netherlands)
LVP	Low Visibility Procedures
MON	Minimum Operating Network
MUAC	Maastricht Upper Area Control Centre
NAVAID(s)	Navigation Aid(s)
NextGen	Next Generation (USA ATM system)
NDB	Non-Directional Beacon
NPA	Non-Precision Approach
PA	Precision Approach
PBN	Performance Based Navigation
PCP	Pilot Common Project Regulation
RF	Radius to Fix
PinS	Point in Space
RNAV	Area Navigation
RNP	Required Navigation Performance
RNP APCH	RNP Approach
RNP AR APCH	RNP Approach with Authorisation Required
RPAS	Remotely Piloted Aircraft Systems

RWY	Runway
SAR	Search And Rescue
SBAS	Satellite-based Augmentation System
SESAR	Single European Sky ATM Research and Development Programme
SID	Standard Instrument Departure
SRAP	Second Runway Aiming Point
STAR	Standard Arrival Route
TACAN	TACtical Air Navigation
TMA	Terminal Maneuvering Area
U-space	Services and procedures related for safe, efficient and secure access to airspace for large numbers of drones
VFR	Visual Flight Rules
VNAV	Vertical Navigation
VOR	Very High Frequency Omnidirectional Radio Range
xLS	Any precision approach landing system

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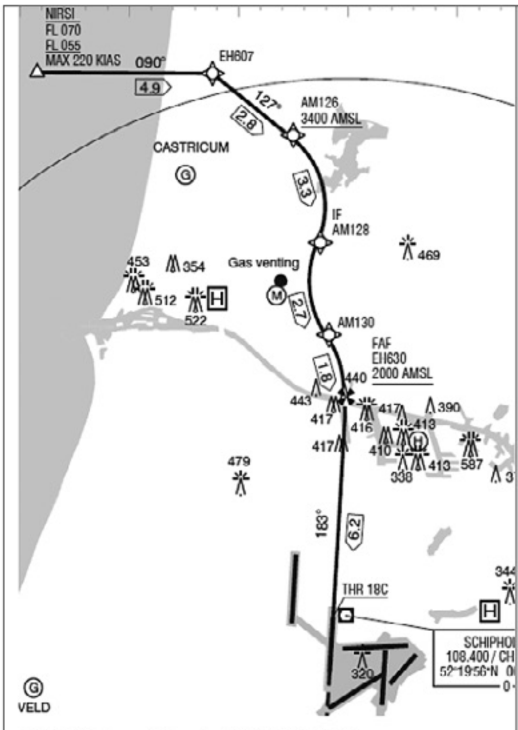
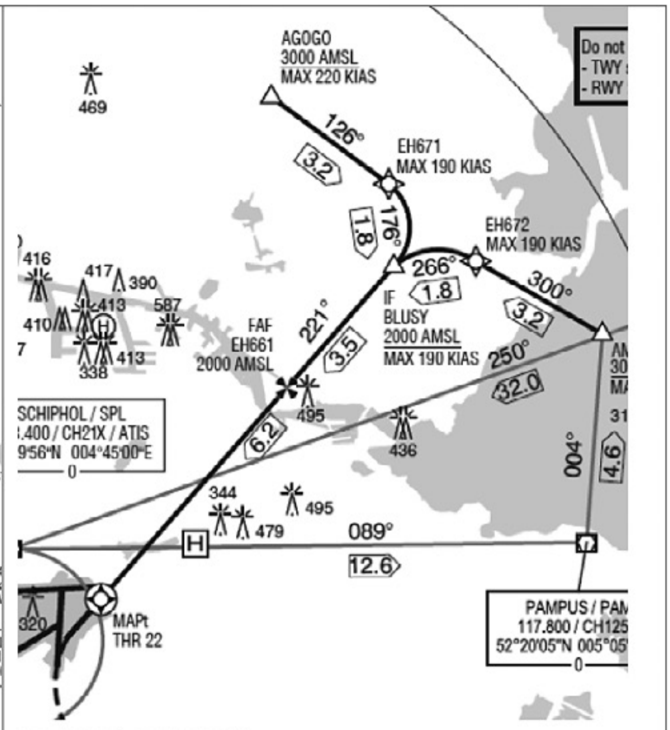
Appendix I:

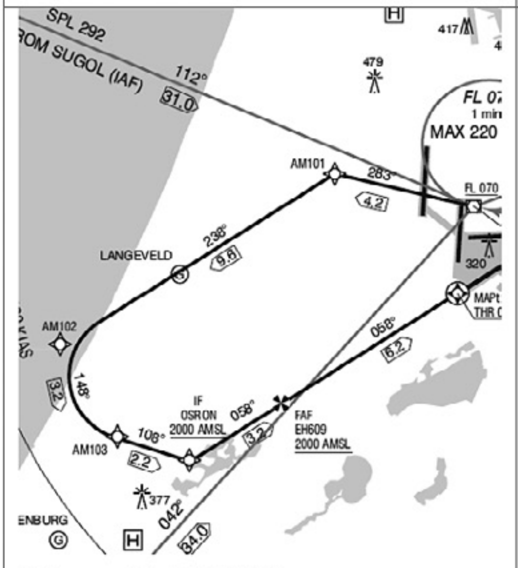
Examples of current PBN implementations in The Netherlands



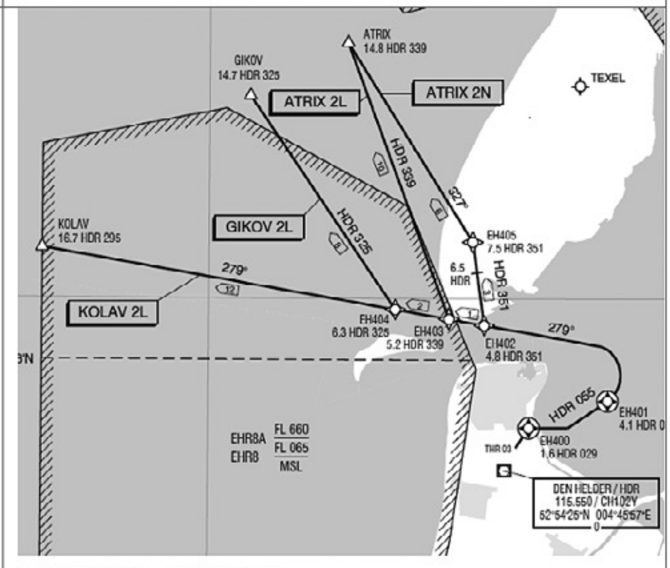
RNP Night transition for EHAM RWY18C



RNP APCH for EHAM RWY22



RNP approach to EHAM RWY 06



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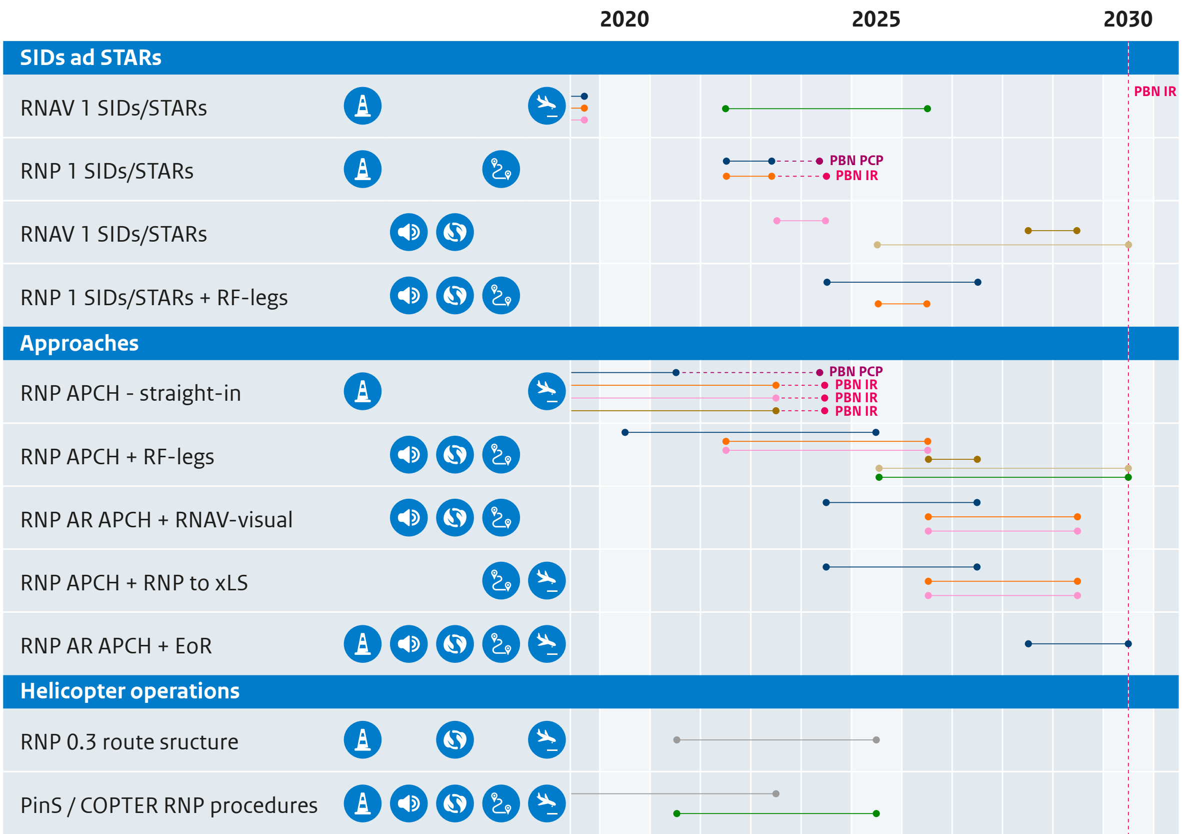
Appendix II:

PBN roadmap 2020-2030



Legenda

- Schiphol
- National Airports - SPL TMA
- National Airports - Non-SPL TMA
- Regional IFR Airports
- Regional Non-IFR Airports
- Military Airports & Heliports
- Civil Heliports

- PBN PCP mandate
- PBN IR mandate

- Safe traffic flows
- Noise abatement
- Reduced emissions
- Predictable flight tracks
- Airport accessibility

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