European Aviation Safety Agency

# Notice of Proposed Amendment 2015-01

# Performance-Based Navigation (PBN) implementation in the European Air Traffic Management Network (EATMN)

RMT.0639 — 19.1.2015


**EXECUTIVE SUMMARY**

This Notice of Proposed Amendment (NPA) addresses the safety, interoperability, proportionality and coordination issues related to the implementation of Performance Based Navigation (PBN) within European airspace.

The specific objective is to ensure a safe, efficient and harmonised implementation of specific PBN specifications and functionality in the European ATM Network (EATMN). In achieving this objective, the proposal, which extends the PBN implementation requirements beyond the 24 EU aerodromes as required by the Pilot Common Project Regulation, mitigates the risks associated with a non-harmonised implementation, thus ensuring a smooth transition to PBN operations, fully supporting the implementation of the European Air Traffic Management Master Plan. The proposal builds on the accepted conclusions defining the navigation specifications and functionality that should be implemented in the European airspace, resulting from a previous European Commission mandate issued to EUROCONTROL for the preparation of a Single European Sky interoperability Implementing Regulation for PBN.

This NPA proposes that Air Traffic Service Providers (ATSPs) and aerodrome operators implement:

— PBN Standard Instrument Departure (SID)/Standard Instrument Arrival (STAR) and Air Traffic Service (ATS) routes as required to meet locally defined performance objectives that conform to RNP1 perfomance requirements as of December 2018; and

— PBN approach procedures with vertical guidance (APV) (RNP APCH) at all instrument runway ends where there are currently only non-precision approach procedures published before January 2024.

Aircraft operators wishing to operate these routes and procedures will be required to ensure that their aircraft and filght crew are approved for PBN operations.

This proposal is expected to increase safety, improve harmonisation of PBN operation and be consistent with the ATM Functionality AF 1 — 'Extended AMAN and PBN in high density TMAs; of Commission Implementing Regulation (EU) No 716/2014 — 'Pilot Common Project'.


| **Applicability** | | **Process map** | |
|---|---|---|---|
| Affected regulations and decisions: | Regulation (EU) No 1332/2011; Regulation(EU) No 965/2012; ED Decision 2012/002/R. | Concept Paper: | No |
| | | Terms of Reference: | 25.6.2014 |
| | | Rulemaking group: | No |
| Affected stakeholders: | Member States; ATM/ANS providers; aerodrome operators. | RIA type: | Full |
| | | Technical consultation during NPA drafting: | No |
| Driver/origin: | Legal obligation (EU Mandate for PBN Operations; Commission Regulation (EU) No 716/2014 — Pilot Common Project). | Duration of NPA consultation: | 3 months |
| | | Review group: | TBD |
| Reference: | EC mandate for an IR on PBN (MOVE E2/EMM D(2011) (6.4.2011). | Focussed consultation: | Yes |
| | | Publication date of the Opinion: | 2015/Q2 |
| | | Publication date of the Decision: | 2015/Q4 |

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# 1. Procedural information

## 1.1. The rule development procedure

The European Aviation Safety Agency (hereinafter referred to as the 'Agency') developed this Notice of Proposed Amendment (NPA) in line with Regulation (EC) No 216/2008[1] (hereinafter referred to as the 'Basic Regulation') and the Rulemaking Procedure[2].

This rulemaking activity is not included in the Agency's 4-year Rulemaking Programme. It was introduced at the request of the European Commission to develop the regulatory provisions for a harmonised European PBN implementation in support of the Pilot Common Project. The task has been defined under RMT.0639 — ToR RMT.0639 published on 25 June 2014.

The text of this NPA has been developed by the Agency with the assistance of EUROCONTROL for the establishment of the means of compliance and impact anaylsis. It is hereby submitted for consultation of all interested parties[3].

The process map on the title page contains the major milestones of this rulemaking activity to date and provides an outlook of the timescale of the next steps.

## 1.2. The structure of this NPA and related documents

Chapter 1 of this NPA contains the procedural information related to this task. Chapter 2 (Explanatory Note) explains the core technical content. Section 3 contains the proposed text for the new and amended requirements. Chapter 4 contains the Regulatory Impact Assessment (RIA) showing which options were considered and what impacts were identified, thereby providing the detailed justification for this NPA.

## 1.3. How to comment on this NPA

Please submit your comments using the automated **Comment-Response Tool** (CRT) available at http://hub.easa.europa.eu/crt/[4] The Agency is addressing stakeholders in order to receive further guidance during the consultation of this NPA with a view to gaining additional information and the opinion of a wider audience.

The deadline for submission of comments is **20 April 2015**.

[1] Regulation (EC) No 216/2008 of the European Parliament and of the Council of 20 February 2008 on common rules in the field of civil aviation and establishing a European Aviation Safety Agency, and repealing Council Directive 91/670/EEC, Regulation (EC) No 1592/2002 and Directive 2004/36/EC (OJ L 79, 19.3.2008, p. 1).

[2] The Agency is bound to follow a structured rulemaking process as required by Article 52(1) of the Basic Regulation. Such process has been adopted by the Agency's Management Board and is referred to as the 'Rulemaking Procedure'. See Management Board Decision concerning the procedure to be applied by the Agency for the issuing of Opinions, Certification Specifications and Guidance Material (Rulemaking Procedure), EASA MB Decision No 01-2012 of 13 March 2012.

[3] In accordance with Article 52 of the Basic Regulation and Articles 5(3) and 6 of the Rulemaking Procedure.

[4] In case of technical problems, please contact the CRT webmaster (crt@easa.europa.eu).

## 1.4. The next steps in the procedure

Following the closing of the NPA public consultation period, the Agency will review all received comments and may perform a focussed consultation which will consist of (a) thematic review meeting(s) dependent upon the comments received.

The outcome of the NPA public consultation as well as that of any focussed consultation will be reflected in the respective Comment-Response Document (CRD).

The Agency will publish the CRD simultaneously with the Opinion containing proposed changes to the EU regulations listed in Chapter 5.1. The Opinion is addressed to the European Commission, which uses it as a technical basis to prepare the legislative proposals to amend the affected Regulations.

The Decision containing the amendments to the related Acceptable Means of Compliance (AMC) and Guidance Material (GM) listed in Chapter 5.2 will be published by the Agency when the related Implementing Rule(s) is/are adopted by the Commission.

# 2. Explanatory Note

## 2.1. Proposed provisions

In order to enable the introduction of PBN within the EATMN, a Performance-Based approach has been adopted by the Agency. Whereby it is recognised that PBN routes should only be implemented where required to meet defined local performance objectives, with the exception of approach procedures for which a mandate is proposed. The entities directly affected by the proposed regulation and their obligations, as summarised in Figure 1, are:

— Air Traffic Service Providers (ATSPs) when implementing Standard Instrument Departure (SID)/Standard Instrument Arrival (STAR) in order to meet local performance objectives shall conform to RNP 1 perfomance requirements as of December 2018;

— Air Traffic Service Providers (ATSPs) in coordination with the Network Manager when implementing PBN ATS routes in order to meet network performance objectives shall conform to RNP 1 perfomance requirements as of December 2018; and

— Air Traffic Service Providers (ATSPs) and aerodrome operators shall implement PBN Appoach Procedures with Vertical guidance (APV) conforming to the ICAO RNP APCH requirements at all instrument runway ends where currently, there is only a non-precision approach procedure in place by January 2024.

No direct obligation has been proposed to aircraft operators. The obligation to equip and qualify flight crew is already addressed in the existing regulations, whereas the relevant requirements for aircraft operators are set out in:

Commission Regulation (EU) No 965/2012[5]

'ORO.GEN.110 Operator responsibilities

(…)

*(d) The operator shall ensure that its aircraft are equipped and its crews are qualified as required for the area and type of operation.'*

(…)

and

Commission Regulation (EU) No 923/2012[6]

'SERA.5015 Instrument flight rules (IFR) — Rules applicable to all IFR flights:

*(a) Aircraft equipment*

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5 Commission Regulation (EU) No 965/2012 of 5 October 2012 laying down technical requirements and administrative procedures related to air operations pursuant to Regulation (EC) No 216/2008 of the European Parliament and of the Council (OJ L 296, 25.10.2012, p. 1)

6 Commission Implementing Regulation (EU) No 923/2012 of 26 September 2012 laying down the common rules of the air and operational provisions regarding services and procedures in air navigation and amending Implementing Regulation (EU) No 1035/2011 and Regulations (EC) No 1265/2007, (EC) No 1794/2006, (EC) No 730/2006, (EC) No 1033/2006 and (EU) No 255/2010 (OJ L 281, 13.10.2012, p. 1).

*Aircraft shall be equipped with suitable instruments and with navigation equipment appropriate to the route to be flown and in accordance with the applicable air operations legislation.'*

Futhermore, in implementing a performance-based approach, it is recognised that aircraft operators for whom it may not be economical to modify aircraft to operate on PBN routes and procedures should not be excluded from all operations. Therefore, an additional obligation has been proposed for ATSPs and aerodrome operators to ensure that approach procedures, SID/STAR and ATS routes based on non-PBN applications are available but may be limited in application, commensurate with the operational performance needs of the aerodrome or airspace.

**Figure 1: Proposed regulatory provisions**


In developing the proposed provisions, the Agency has taken due account of the envisaged performance improvements that can be gained from PBN operations in terms of safety and efficiency. The Agency also acknowledges that a significant number of the current and future aircraft population already have, or are planned to have, the on-board capabilities to perform most of the PBN operations that are currently defined by ICAO. It is also recognised that on-board capability is limited in its use due to the non-availability of published routes and procedures.

In addition to the introduction of the obligations for PBN, a change has been proposed to the scope of the regulation compared to that of Commission Regulation (EU) No 1332/2011, with the addition of a clause limiting its applications with respect to aircraft undertaking maintenance, delivery or flight testing.

Evidence has shown that mandating aircraft manufactured or being maintained within Europe to be equipped specifically for a one-off operation within European airspace can be detrimental to the airspace industry. As such a provision has been established, that aircraft undertaking maintenance, delivery or flight testing are permitted to operate in the airspace. However, such operations may be subject to additional restrictions dependent upon the intended route.

## 2.2. Selection of PBN requirements

### *2.2.1. Alignment issues*

The Pilot Common Project Regulation[7] requires 25 aerodromes (including one non-European aerodrome) to implement an 'Enhanced Terminal Airspace using Required Navigation Performance (RNP)-Based Operations' that comprises;

— RNP 1 SIDs, STARs and transitions (with the use of the Radius to Fix (RF) attachment); and

— RNP APCH (Lateral Navigation/Vertical Navigation (LNAV/VNAV) and Localiser Performance with Vertical Guidance (LPV) minima)

The remaining 565 aerodromes within Europe fulfilling the requirements of the Basic Regulation defined as follows:

— be open to public use; and

— serve commercial air transport where operations using instrument approach or departure procedures are provided; and

  - have a paved runway of 800 metres or above; or
  - exclusively serve helicopters,

are at liberty to implement or adapt any of the applicable PBN specifications published by ICAO. It is, therefore, necessary to harmonise the PBN implementation in Europe by reducing or limiting the number of options that may be applied. Therefore, in the absence of appropriate, proportionate and specific regulations, the current situation, whereby routes and procedure designs will proliferate based on different PBN specifications, will continue.

Furthermore, although it is the Network Manager's responsibility to coordinate the implementation of the fixed route network, the Member States are at liberty to require the implementation of any of the applicable PBN specifications. Such a possible fragmented application of PBN would result in a complex airspace structure and operational procedures as a consequence of numerous transitions between the various possible PBN Navigation Specifications areas.

Regulatory measures are therefore required to achieve a safe, efficient and harmonised PBN implementation in the EATMN that support an improved operation of the network and are consistent with the requirements as specified in the Pilot Commom Project.

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[7] Commission Implementing Regulation (EU) No 716/2014 of 27 June 2014 on the establishment of the Pilot Common Project supporting the implementation of the European Air Traffic Management Master Plan (OJ L 190, 28.6.2014, p. 1).

### 2.2.2. Selection of PBN requirements

Prior to the initiation of this rulemaking task, a European Commission mandate (see Chapter 5.3) to EUROCONTROL had been issued for the preparation of a Single European Sky interoperability Implementing Regulation on PBN. The conclusions resulting from the EUROCONTROL consultation have been published in EUROCONTROL's Regulatory Approach Document, including the preliminary impact assessment (see Chapter 5.3). This Regulatory Approach Document defined the proposed navigation specifications and functionalities that should be implemented in the European airspace. This proposal, as shown in Table 1 for reference, has been presented to and accepted by the relevant stakeholders and Member States.

As a result of this prior consultation, the identification of the specific navigation specifications to be implemented is not included in this rulemaking task. The Agency took due account of the European concept for PBN operations; the regulatory provisions applicable to Air Traffic Service Providers and aerodrome operators are built on said EUROCONTROL consultation, reflect required aircraft performance requirements and are aligned with the applicability dates of the PCP Regulation.

**Table 1: Proposed PBN Requirements**

| Date of applicability of:<br>— Certification and operational approval for aircraft and<br>— implementation for Service Provider | PHASE OF FLIGHT | | | | | | |
|---|---|---|---|---|---|---|---|
| | En Route | | | Terminal | | Final Approach | |
| | Aircraft | | Service Provision | Aircraft | Service Provision | Aircraft | Service Provision |
| | Above FL195 | Below FL195 | | | | | |
| By end 2018 | | | | | | | RNP APCH (APV, where appropriate, subject to operational needs but LNAV as a minimum) |
| By end 2020 | | | | RNP1<br>+<br>RF leg<br>+<br>RNAV Holding<br>+<br>Ability to meet altitude constraints, i.e. 'AT', 'AT OR ABOVE', 'AT OR BELOW', 'WINDOWS'. | Provide RNP SIDs and STARs<br>Use of altitude constraints<br>Optimise TMA flows to provide:<br>— Capacity<br>— Efficiency<br>— Access<br>— CDO/CCO based on positive CBA | APV<br>(either Baro or SBAS) | |

| Date of applicability of:<br>— Certification and operational approval for aircraft and<br>— implementation for Service Provider | PHASE OF FLIGHT | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | En Route | | | Terminal | | Final Approach | | |
| | Aircraft | | Service Provision | Aircraft | Service Provision | Aircraft | Service Provision |
| | Above FL195 | Below FL195 | | | | | |
| | | | | | | | |
| By end 2023 | Advanced RNP<br>+<br>FRT | RNP1<br>+<br>RNAV Holding | Airspace designed to optimise flight efficiency.<br>— Free routes airspace enabling user-preferred trajectories.<br>— High density airspace redesigned for closer space routes and route conformance monitoring tools implemented to manage traffic | | | | |

| Date of applicability of:<br>— Certification and operational approval for aircraft and<br>— implementation for Service Provider | PHASE OF FLIGHT | | | | | | |
|---|---|---|---|---|---|---|---|
| | En Route | | | Terminal | | Final Approach | |
| | Aircraft | | Service Provision | Aircraft | Service Provision | Aircraft | Service Provision |
| | Above FL195 | Below FL195 | | | | | |
| | | | — Use of altitude constraints | | | | |

## 2.3. Overview of the issues to be addressed

The continued growth of aviation places increasing demands on the effective and efficient use of the available airspace, thus emphasising the need for its optimum utilisation. Improved operational efficiency and airspace utilisation, derived from the application of Performance-Based Navigation (PBN), has been demonstrated to bring capacity benefits through the optimisation of Air Traffic Service (ATS) routes and approach procedures. PBN is, therefore, one of the underpinning operational concepts required to improve the efficiency of European aviation operations and is being implemented worldwide as part of the ICAO Global Air Navigation Plan (GANP).

PBN offers a number of advantages over the conventional sensor-specific methods of developing and operating on routes and approach procedures. For instance, PBN:

(a) reduces the need to maintain sensor-specific routes and procedures, and their associated costs;

(b) avoids the need for the development of sensor-specific operations. The expansion of Global Navigation Satellite Systems (GNSS) is expected to contribute to the continued implementation of PBN operations. The original basic GNSS equipment is evolving due to the development of augmentations such as the Satellite-Based Augmentation System (SBAS);

(c) allows for a more efficient use of the airspace (route placement, fuel efficiency, noise abatement, etc.), in particular in the terminal areas;

(d) clarifies the way in which Area Navigation (RNAV) and Required Navigation Performance (RNP) systems are used.

In order to ensure an efficient, harmonised and safe implementation of PBN in Europe, that enables a performance improvement of the European Air Traffic Management Network (EATMN), the harmonised use of the PBN specifications and functionalities is critical. The efficient and safe use of the European ATS route network and the efficient and safe access to European aerodromes are to be ensured based on a common application of standardised PBN specifications and functionalities.

Each Member State, ATM/ANS provider or aerodrome operator implementing routes/procedures designed on the basis of a PBN specification or functionality of their choice would lead to a fragmented, non-harmonised, inefficient and potentially unsafe PBN implementation in the European airspace.

For more detailed analysis of the issues addressed by this proposal, please refer to the RIA section 4.1. 'Issues to be addressed'.

## 2.4. Objectives

The overall objectives of the EASA system are defined in Article 2 of the Basic Regulation. This proposal will contribute to the achievement of these overall objectives by addressing the issues outlined in paragraph 2.1 of this NPA. The proposal will also contribute to the implementation of the essential requirements of Regulation EC (No) 552/2004[8] — Annex II, Part-A.

Furthermore, the provisions as proposed in this NPA:

(a) have been developed to be consistent with the ATM Functionality AF 1 — Extended AMAN and PBN in high density TMAs of the Pilot Common Project Regulation, supporting the implementation of the European Air Traffic Management Master Plan.

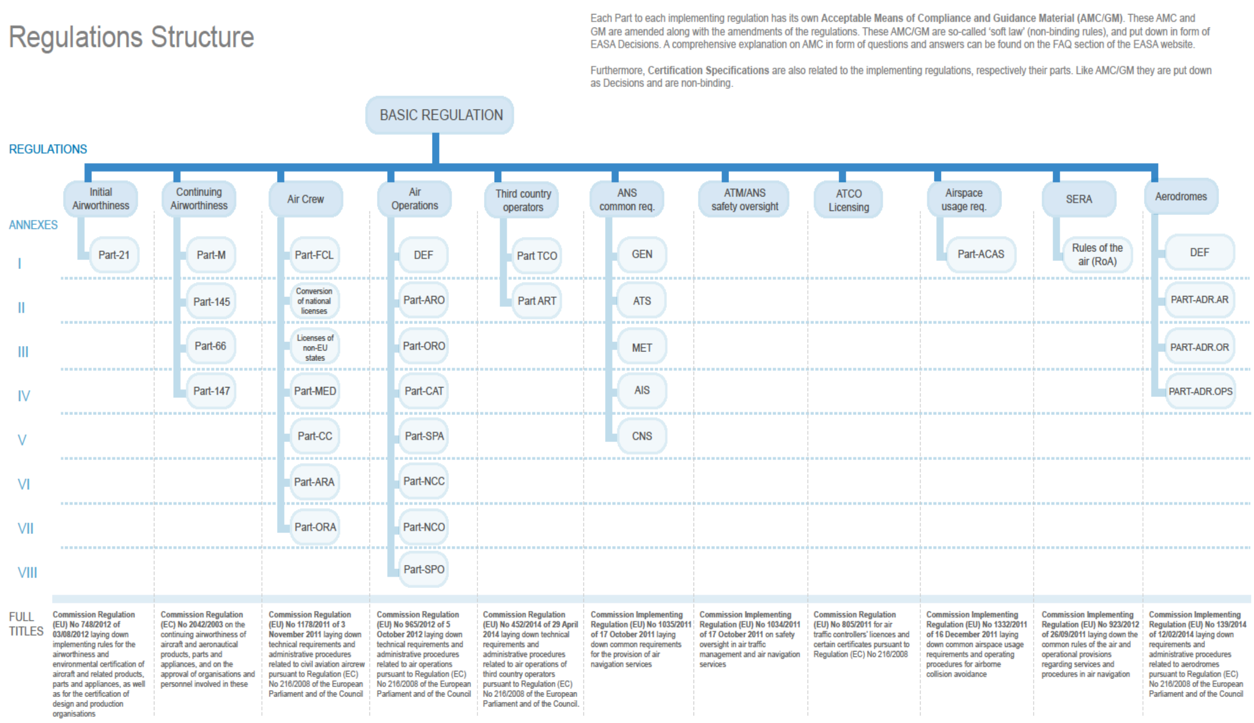
(b) enable a performance-based application of PBN within the EATMN.

The specific objective of this proposal is, therefore, to ensure a safe, efficient and harmonised implementation of specific PBN specifications and functionalities in the EATMN.

## 2.5. Regulatory overview

Through the application of the 'Total System Approach' and following the principles of 'Better regulation', the Agency undertook a review of the current regulatory framework (see Figure 2) to ascertain the best approach and the regulation(s) in which to include the PBN implementation requirements.

**Figure 2: Current EASA regulatory framework**




[8] Regulation (EC) No 552/2004 of the European Parliament and of the Council of 10 March 2004 on the interoperability of the European Air Traffic Management network (the interoperability Regulation) (OJ L 96, 31.3.2004, p. 26).

The creation and proliferation of individual regulations for the implementation of individual technical enablers was considered not to be appropriate as this would result in a confused and complex regulatory environment. The regulatory requirements and means of compliance should be a set of harmonised and complementary provisions, allocated as appropriate within each stakeholder's regulatory domain. Such an approach reduces the complexity of the regulatory system, thus supporting a better understanding and, hence, implementation of the safety and interoperability requirements in all domains.

In applying this principle, it was considered that a single regulation containing the mandated requirements applicable to **all** airspace users and to the use of the airspace would be appropriate. Therefore, achieving the following would be pertinent:

— lay down common airspace usage and operating procedures to be applied above the territory to which the Treaty applies; and

— be applicable to:

- operations of aircraft registered in a Member State and Aircraft registered in a third country and operated by a Member State operator;
- operations of aircraft by a third country operator;
- aerodrome operations; and
- ATM/ANS provision.

The detailed requirements to enable PBN operations associated with each domain are included in the regulations, Certification Specifications (CSs) and Acceptable Means of Compliance (AMC)/Guidance Material (GM) that are applicable to the individual domains (see Chapter 2.7 for additional information).

Within the Agency's regulatory framework, the sole regulation that currently contains only one mandated equipage requirement is Regulation (EU) No 1332/2011[9]. This Regulation was adopted by the European Commission on the basis of the Agency's Opinion 05/2010[10] on common airspace usage requirements and operating procedures for which the initial application was the mandated use of ACAS II with software version 7.1.

In reviewing the applicability of said Regulation as published, it was noted that it lays down common airspace usage requirements and operating procedures for airborne collision avoidance to be applied by:

(a) operators of aircraft referred to under Article 4(1)(b) and (c) of Regulation (EC) No 216/2008 undertaking flights into, within or out of the Union; and

[9] Commission Regulation (EU) No 1332/2011 of 16 December 2011 laying down common airspace usage requirements and operating procedures for airborne collision avoidance (OJ L 336, 20.12.2011, p. 20).

[10] http://easa.europa.eu/document-library/opinions/opinion-052010

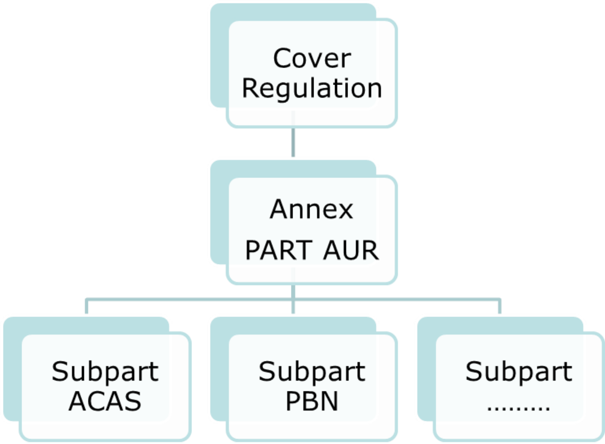
(b) operators of aircraft referred to under Article 4(1)(d) of Regulation (EC) No 216/2008 undertaking flights within the airspace above the territory to which the Treaty applies as well as in any other airspace where Member States apply Regulation (EC) No 551/2004.

As this scope is not fully aligned with the scope detailed above, an amendment to the scope or a new regulation would be needed. As already indicated, through the application and principles of 'Total System Approach' and 'Better regulation', a single regulation would be the preferred option for all mandated airspace usage requirements. This NPA, therefore, proposes to repeal Commission Regulation (EU) No 1332/2011. The repealed regulation is to be replaced with a recast regulation, containing the same obligations related to ACAS II, as it would be amended in accordance with Opinion 4/2014 — 'Amendment to Commission Implementing Regulation (EU) No 923/2012 laying down the common rules of the air and operational provisions regarding services and procedures in air navigation (SERA Part C)[11], as well as the requirement to support PBN implementation.

The structure of the proposed regulation is shown in Figure 3. This proposed structure creates a single regulatory framework that is easily expandable to include other subject matters to support the implementation of the European ATM Master Plan.

[11] http://easa.europa.eu/document-library/opinions/opinion-042014

**Figure 3: Proposed new regulation structure**




- **Cover Regulation**: Full scope, definitions, applicability dates, etc.
- **Subpart ACAS**: Specific scope and ACAS II carriage obligations
- **Subpart PBN:** Specific scope and PBN use obligations
- **Subpart …**: Specific scope and …?

## 2.6. State aircraft

One of the primary concerns of Member States is the continued access to the airspace for State and military aircraft, when undertaking operations or training as General Air Traffic (GAT), and the associated cost incurred by governments to modify the military fleets. To reduce the impact on States, specific exemption conditions or transitions have been previously included in the relevant interoperability regulations.

With respect to this proposal, no such exemptions or transitions are envisaged as the proposed regulation requires, subject to identified performance needs, that procedures and routes based on conventional navigation aids will be maintained. This will, therefore, permit non-PBN-capable State aircraft to continue to operate; however, their operations may be limited with respect to access times and may not always have the most direct routings.

In accordance with Annex II to Regulation (EC) No 552/2004, civil/military coordination shall support, to the extent necessary, effective airspace and air traffic flow management. Furthermore, in accordance with Article 1.2(a) of the Basic Regulation, Member States shall take due account of the objective, as far as practicable, for aircraft engaged in State activities. Therefore, it is anticipated that, where practicable, States will have aircraft and crew qualified for PBN operations.

## 2.7. Overview of regulatory activities currently in progress

In order to implement PBN operations, a series of harmonised and complementary regulations and AMC/GM is required across all aviation domains. In particular, PBN requires:

— aircraft with the required functionality;

— air operators trained on the operations;

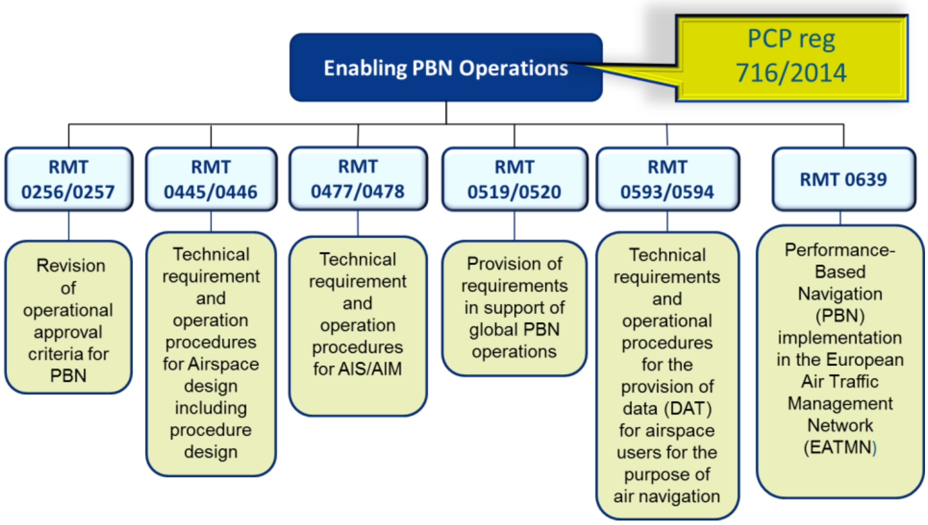
— ATC trained on the operations;

— consistent aeronautical data; and

— accurate and sufficient ground and space infrastructure.

Such regulations and AMC/GM are the enablers of a harmonised PBN application within Europe. Therefore, the Agency has initiated a number of rulemaking tasks to facilitate the use of PBN in Europe and globally. These tasks, as shown in Figure 4, define the revised aircraft certification requirements, pilot/flight crew training and licensing requirements, and the provision of correct data.

**Figure 4: Rulemaking tasks to facilitate PBN operations**



## 2.8. Summary of the Regulatory Impact Assessment (RIA)

### *2.8.1. Options*

Two basic options have been considered:

| *Option No* | *Short title* | Description |
|---|---|---|
| 0 | Do nothing | Baseline option (no change in rules; risks remain as outlined in the issue analysis). |
| 1 | Harmonised PBN implementation | Proposed regulation to mandate implementation of APV approaches at all instrument runway ends where there is no precision approach procedure and to ensure harmonised PBN implementation in Europe where and when needed to reach performance criteria. |

### *2.8.2. Summary of the impact analysis*

The summary of the impacts for each option is provided in the following table:

| *Type of impacts* | *Option 0* | *Option 1* |
|---|---|---|
| Safety | 0 to + | + |
| Environmental | 0 to + | + |
| Economic | – to + | + |
| Proportionality | 0 | 0 to + |
| 'Better regulation' and harmonisation | – to 0 | + |
| Cumulated impact assessment | 0 to + | + |

The provision of a regulation enabling a harmonised implementation of PBN operations is considered to be the preferred option. This option provides the highest benefits in terms of increasing safety, particularly with respect to approach operations, while enabling a harmonised application of PBN operations. In addition although not directly addressed in the regulation, aircraft operators will only need to qualify their aircraft and crews to enable operations in accordance with a limited number of navigation specifications. For further details, see Chapter 4.

# 3. Proposed amendments

The text of the amendment is arranged to show deleted text, new or amended text as shown below:

(a) deleted text is marked with ~~strike through~~;

(b) new or amended text is highlighted in grey;

(c) an ellipsis (…) indicates that the remaining text is unchanged in front of or following the reflected amendment.

## 3.1. Draft Regulation (Draft EASA Opinion)

### *3.1.1. COMMISSION IMPLEMENTING REGULATION (EU) No …/of […] laying down common airspace usage requirements and operating procedures repealing Commission Regulation (EU) No 1332/2011*

Article 1

**Subject matter and scope**

~~This Regulation lays down common airspace usage requirements and operating procedures for airborne collision avoidance to be fulfilled by:~~

~~(a) operators of aircraft referred to under Article 4(1)(b) and (c) of Regulation (EC) No 216/2008 undertaking flights into, within or out of the Union; and~~

~~(b) operators of aircraft referred to under Article 4(1)(d) of Regulation (EC) No 216/2008 undertaking flights within the airspace above the territory to which the Treaty applies as well as in any other airspace where Member States apply Regulation (EC) No 551/2004 of the European Parliament and of the Council[2].~~

(a) This Regulation lays down common airspace usage requirements and operating procedures to be applied above the territory to which the Treaty applies as well as in any other airspace in accordance with Article 1.3 of Regulation (EC) No 551/2004[12].

(b) This Regulation shall apply to:

(1) aircraft operations as referred to in Article 4(3) of Regulation (EC) No 216/2008;

(2) aerodrome Operations as referred to in Article 4(3a) of said Regulation; and

(3) ATM/ANS provisions as referred to in Article 4(3c) of said Regulation.

(c) This Regulation shall not apply to operations of aircraft referred to in Article 4(3) of Regulation (EC) No 216/2008 undertaking operations for the purpose of maintenance, delivery or flight testing.

(d) Member States shall undertake to ensure that operations of aircraft referred to in Article 1(2)(a) and the facilities and services referred to in Articles 1(2)(b) and 1(2)(c) of Regulation (EC) No 216/2008 when used by or made available to the public have due regard to the provisions of this Regulation.

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[12] Regulation (EC) No 551/2004 of the European Parliament and of the Council of 10 March 2004 on the organisation and use of the airspace in the single European sky (the airspace Regulation) (OJ L 96, 31.3.2004, p. 20).

Article 2

**Definitions**

For the purposes of this Regulation, in addition to the definitions established by Regulations (EC) Nos 216/2008 and 1035/2011, and Regulations (EU) Nos 923/2012, 965/2012 and 139/2014[13], the following definitions shall apply.

(1) 'airborne collision avoidance system (ACAS)' means an aircraft system based on secondary surveillance radar (SSR) transponder signals which operates independently of ground-based equipment to provide advice to the pilot on potential conflicting aircraft that are equipped with SSR transponders;

(2) 'airborne collision avoidance system II (ACAS II)' means an airborne collision avoidance system which provides vertical resolution advisories in addition to traffic advisories;

(3) 'area navigation' means a method of navigation which permits aircraft operation on any desired flight path within the coverage of ground or space-based navigation aids or within the limits of the capability of self-contained aids, or a combination of these;

(4) 'fix radius transition (FRT)' is defined as a fixed radius turn between two route segments;

(5) 'performance-based navigation' (PBN) means area navigation based on performance requirements for aircraft operating along an ATS route, on an instrument procedure or in a designated airspace;

(6) 'radius to Fix (RF)' is defined as a constant radius circular path about a defined turn centre that terminates at a fix;

(7) 'resolution advisory (RA) indication' means an indication given to the flight crew recommending a manoeuvre intended to provide separation from all threats or a manoeuvre restriction intended to maintain existing separation;

(8) 'satellite-based augmentation system (SBAS)' means a wide coverage GNSS augmentation system through which the user receives augmentation information from a satellite-based transmitter;

(9) 'Standard Instrument Arrival (STAR)' route means a designated instrument flight rule (IFR) arrival route linking a specified significant point, normally on an ATS route, with a point at which a published instrument approach procedure can be commenced;

(10) 'Standard Instrument Departure (SID)' route means a designated instrument flight rule (IFR) departure route linking the aerodrome or a specified runway of the aerodrome with a specified significant point, normally on a designated ATS route, at which the en route phase of a flight commences;

(11) 'Total System Error (TSE)' means the difference between true position and intended position;

(12) 'traffic advisory (TA) indication' means an indication given to the flight crew that the proximity of another aircraft is a potential threat.

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[13] Commission Regulation (EU) No 139/2014 of 12 February 2014 laying down requirements and administrative procedures related to aerodromes pursuant to Regulation (EC) No 216/2008 of the European Parliament and of the Council (OJ L 44, 14.2.2014, p. 1).

Article 3

**~~Airborne collision avoidance system (ACAS)~~ Airspace usage**

~~1.The aeroplanes referred to in Section I of the Annex to this Regulation shall be equipped with and operated in accordance with the rules and procedures as specified in the Annex.~~

~~2.Member States shall ensure that operation of aeroplanes referred to in Article 1(2)(a) of Regulation (EC) No 216/2008 comply with the rules and procedures specified in the Annex in accordance with the conditions set out in that Article.~~

1.The aircraft operators as defined in AUR.ACAS.1005 shall be equipped as specified in Subpart ACAS of the Annex to this Regulation.

2.The Air Traffic Service Providers (ATSPs) and aerodrome operators as defined in AUR.PBN.1005 shall comply with the rules and procedures as specified in subpart PBN of the Annex to this Regulation.

Article 4

**Special provisions applying to operators subject to Regulation (EU) No 965/2012**

1.By derogation from provisions CAT.IDE.A.155 and CAT.OP.MPA.295, NCC.IDE.A.140, NCO.OP.200, NCC.OP.220 and SPO.IDE.A.131 , Article 3(1) and ~~the Annex~~ subpart ACAS to this Regulation shall apply for operators of aeroplanes referred to in Article 1(b)(1).

2.Any other obligation imposed on air operators by Commission Regulation (EU) No 965/2012 as regards the approval, installation or operation of equipment shall continue to apply to ACAS II.

Article 5

**Repeals**

Commission Regulation (EU) No 1332/2011 is hereby repealed.

Article 6

**Entry into force**

1.This Regulation shall enter into force on the twentieth day following that of its publication in the *Official Journal of the European Union* and shall apply as from 6 December 2018.

~~2.Articles 3 and 4 shall apply as of 1 March 2012.~~

~~3.By way of derogation from paragraph 2, in the case of aircraft with an individual certificate of airworthiness issued before 1 March 2012, the provisions of Article 3 and 4 shall apply as of 1 December 2015.~~

2.By way of derogation from paragraph 1 the provisions as defined in the Annex , Subpart PBN, AUR.PBN. 2005(1) shall apply as from 26 January 2024.

(…)

**ANNEX**

**PART-AUR**

**SUBPART ACAS — Airborne Collision Avoidance Systems (ACAS) II**

**AUR.ACAS.1005 Scope**

This Subpart establishes the specific requirements for the carriage of ACAS II equipment when undertaking flights within the airspace above the territory to which the Treaty applies by:

(a) operators of aircraft referred to under Article 4(1)(b) and (c) of Regulation (EC) No 216/2008 undertaking flights into, within or out of the Union; and

(b) operators of aircraft referred to under Article 4(1)(d) of said Regulation undertaking flights within the airspace above the territory to which the Treaty applies as well as in any other airspace defined in Article 1.

**AUR.ACAS.2005 Performance requirements**

1) all turbine-powered aeroplanes:

   (a) with a maximum certificated take-off mass exceeding 5 700 kg or;

   (b) authorised to carry more than 19 passengers,

shall be equipped with ACAS II with collision avoidance logic version 7.1;

2) aircraft not referred to in (1) but equipped with ACAS II, shall have collision avoidance logic version 7.1;

3) paragraph (1) shall not apply to unmanned aircraft systems.

## SUBPART PBN — Performance-Based Navigation

### AUR.PBN.1005 Scope

1) This Subpart establishes the specific requirements for the introduction of performance-based navigation applications in the European ATM Network.

2) This Subpart shall apply to:

(a) Air Traffic Service Providers (ATSPs) referred to under Article 1(2) that provide air traffic services (ATS) in the airspace as defined in Article 1(1); and

(b) aerodrome operators referred to under Article 1(2).

## Section I — Airspace

### AUR.PBN.2005 Routes and procedures

(1) ATSPs or aerodrome operators, responsible for the provision of instrument approach procedures, shall implement approach procedures with vertical guidance, that correspond to the performance and functionality as defined in AUR.PBN.2015(1) at all instrument runway ends which are not served by a precision approach procedure.

(2) Without prejudice to paragraph 1, where limiting obstacles conditions exist, ATSPs or aerodrome operators, responsible for the provision of instrument approach procedures, may implement approach procedure with vertical guidance to aerodromes that correspond to the performance and functionality as defined in AUR.PBN.2015(2).

(3) When implementing Standard Instrument Departures (SIDs) and Standard Arrival Routes (STARs), using PBN to meet the airspace performance needs, ATSPs or aerodrome operators, responsible for the provision of the routes, shall ensure that the routes correspond to the performance and fuctionaliity as defined in AUR.PBN.2015(3).

(4) When implementing ATS routes using PBN to meet the network performance needs, the Network Manager, as required by Article 3(4)(a) of Regulation (EU) No 677/2011[14], shall ensure the coordinated design of the European Route Network that corresponds with the performance and functionality as defined in AUR.PBN.2015(4).

### AUR.PBN.2010 Surveillance and communications

ATSPs shall ensure that the surveillance and communications infrastructure has the capabilities needed to support the intended PBN operation.

### AUR.PBN.2015 Performance and functionality

(1) The instrument approach procedures required by AUR.PBN.2005(1) shall be consistent with the following aircraft performance and functionality:

(a) the lateral TSE and the along-track error are within ±1 NM for at least 95 % of the total flight time;

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14 Commission Regulation (EU) No 677/2011 of 7 July 2011 laying down detailed rules for the implementation of air traffic management (ATM) network functions and amending Regulation (EU) No 691/2010 (OJ L 185, 15.7.2011, p. 1)

(b) for the Final Approach Segment when supported by BARO–VNAV:

(i) the lateral TSE and the along-track error is within ±0.3 NM for at least 95% of the total flight time;

(ii) the operations are along a vertical path;

(c) for the Final Approach Segment when supported by SBAS, the angular lateral performance shall be equivalent to (b)(i) and (b)(ii) respectively; and

(d) on-board performance monitoring and alerting.

(2) The instrument approach procedures required by AUR.PBN.2005(2) shall be consistent with the following aircraft performance and functionality:

(a) the lateral TSE and the along-track error are within the applicable value of ±0.1 NM to ±0.3 NM for at least 95 % of the total flight time;

(b) the operations are along a vertical path;

(c) execution of fly-over and fly-by turns and to maintain a track consistent with an RF leg; and

(d) on-board performance monitoring and alerting.

(3) The routes required by AUR.PBN.2005(3) shall be consistent with the following aircraft performance and functionality:

(a) the lateral TSE and the along-track error are within ±1 NM for at least 95 % of the total flight time;

(b) the operations along a vertical path and between two fixes and able to comply with:

(i) an ‘AT’ altitude constraint; or

(ii) an ‘AT OR ABOVE’ altitude constraint; or
(iii) an ‘AT or BELOW’ altitude constraint; or
(iv) a ‘WINDOW’ constraint;

(c) execution of fly-over and fly-by turns and to maintain a track consistent with an RF leg;

(d) on-board performance monitoring and alerting.

(4) The routes required by AUR.PBN.2005(4) shall be consistent with the following aircraft performance and functionality:

(a) above Flight Level 195:

(i) the lateral TSE and along track error are within the applicable accuracy ranging from ±1 NM for at least 95 % of the total flight time;

(ii) the operations along a vertical path and between two fixes and able to comply with:

(A) an ‘AT’ altitude constraint; or
(B) an ‘AT OR ABOVE’ altitude constraint; or
(C) an ‘AT or BELOW’ altitude constraint ; or
(D) a ‘WINDOW’ constraint;

(iii) a flight path transition and track consistent with a fixed radius between two route segments;

(iv) on-board performance monitoring and alerting;

(b) below Flight Level 195:

(i) the lateral TSE and along track error are within the applicable accuracy ranging from ±1 NM for at least 95 % of the total flight time;

(ii) on-board performance monitoring and alerting; and

(iii) holding in a pattern defined by a point, the turn direction, an inbound track and an outbound distance.

**AUR.PBN. 2020 Contingency**

ATSPs and aerodrome operators shall ensure that appropriate contingency procedures are established in case of reported loss of continuity of the navigation.

**Section II — Operations**

**AUR.PBN. 3005 Mixed operations**

(1) ATSPs and aerodrome operators shall ensure that:

(a) approach procedures, Standard Instrument Departures (SID), Standard Arrival Routes (STAR) and ATS routes based on non-PBN applications are available; or

(b) the required operation procedures are available to permit operation of aircraft that do not conform to the requirements to operate on the Standard Instrument Departures, Standard Arrival Routes and ATS routes required by AUR.PBN.2005.

(2) The operational use of such approach procedures and routes required by paragraph 1 may be limited, commensurate with the operational performance needs.

**AUR.PBN. 3010 Coordinated deployment**

(1) Member States, in coordination with the ATSPs and aerodrome operators shall ensure a coordinated and phased implementation of the instrument approach procedures required by AUR.PBN.2005(1).

(2) ATSPs and aerodrome operators shall notify airspace users and the Network Manager of their intent to implement PBN Standard Instrument Departures (SID), Standard Arrival Routes (STAR) and ATS routes as specified in AUR.PBN.2005(3) and AUR.PBN.2005(4), 36 months prior to the implementation date.

### *3.1.2.* Amendment to Commission Regulation (EU) No 965/2012 of 5 October 2012 laying down technical requirements and administrative procedures related to air operations pursuant to Regulation (EC) No 216/2008 of the European Parliament and of the Council.

**CAT.IDE.A.155 Airborne collision avoidance system (ACAS)**

Unless otherwise provided for by Commission Implementing Regulation (EU) No ~~1332/2011~~[insert No of the new Regulation], turbine-powered aeroplanes with an MCTOM of more than 5 700 kg or an MOPSC of more than 19 shall be equipped with ACAS II.

**NCC.IDE.A.140 Airborne collision avoidance system (ACAS)**

Unless otherwise provided for by Commission Implementing Regulation (EU) No ~~1332/2011~~[insert No of the new Regulation], turbine- powered aeroplanes with an MCTOM of more than 5 700 kg or an MOPSC of more than 19 shall be equipped with ACAS II.

**NCO.OP.200 Airborne collision avoidance system (ACAS II)**

When ACAS II is used, operational procedures and training shall be in accordance with Commission Implementing Regulation (EU) No ~~1332/2011~~[insert No of the new Regulation].

**SPO.IDE.A.131 Airborne collision avoidance system (ACAS II)**

Unless otherwise provided for by Commission Implementing Regulation (EU) ~~No 1332/2011~~[insert No of the new Regulation], turbine-powered aeroplanes with an MCTOM of more than 5 700 kg shall be equipped with ACAS II.

## 3.2. Draft Acceptable Means of Compliance and Guidance Material (Draft EASA Decision)

Decision 2012/002/R of the Executive Director of the Agency of 8 March 2012 on the Acceptable Means of Compliance and Guidance Material for Common Airspace Usage Requirements and Operating Procedures 'AMC/GM to AUR'.

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**SUBPART ~~Part~~ ACAS**

**~~Section II — Operations~~**

~~AMC1 AUR.ACAS.2010 ACAS II Training~~

~~(a) GENERAL~~

~~The ACAS II operational procedures and training programmes established by the operator should take into account the guidance material contained in:~~

~~(1) ICAO PANS-OPS, Volume 1[15] Flight Procedures, Attachment A (ACAS Training Guidelines for Pilots) and Attachment B (ACAS High Vertical Rate Encounters) to Part III, Section 3, Chapter 3; and~~

~~(2) ICAO PANS-ATM[16] chapters 12 and 15 phraseology requirements.~~

~~15 ICAO Doc 8168-OPS/611 - PANS-OPS (Procedures for Air Navigation Services-Aircraft Operations), Volume I - Flight Procedures Fifth edition amendment 4.~~

~~16 ICAO Doc 4444-ATM/501 - PANS-ATM (Procedures for Air Navigation Services-Air Traffic Management) Fifteenth edition amendment 3.~~

## SUBPART PBN — Performance-Based Navigation

### AMC1 AUR.PBN.2010 Surveillance and communications

The sources of position information used for surveillance and navigation should be different when deploying PBN operations in European en route or terminal airspace. The ATS surveillance should be provided by a non-cooperative (PSR) or cooperative independent (SSR or WAM) surveillance service as required to support the spacing of proximate RNP ATS routes.

### GM1 AUR.PBN.2010 Surveillance and communications

PBN operations, in particular the RNP specifications and ADS-B surveillance, rely upon GNSS core constellation position determination, and as such, there is a common point of failure in the event of a GNSS core constellation outage. The effect of such a failure is determined by a specific operating environment which is summarised in the following table stepping through different SUR types.

| Surveillance Position | | Navigation Position for RNP routes | | Effects if GNSS lost |
|---|---|---|---|---|
| PSR/SSR or SSR/ADS-B | Ind/Cooperative Independent/Dep | RNP | GNSS core constellation | Radar vectoring possible if no D/D; ADS-B SUR lost if GNSS lost |
| PSR/SSR or SSR/ADS-B | Ind/Cooperative Independent/Dep | RNP | GNSS core constellation (+DME/DME reversion) | Continued navigation in degraded RNAV mode on ATS Routes with Surveillance Monitoring by ATC for limited time; air traffic flow regulation will be needed; ADS-B SUR lost if GNSS lost. |
| ADS-B | GNSS | RNP | GNSS core constellation | Loss of surveillance & navigation position. unacceptable in EUR high density; procedural control might be possible in low density as long as other Navaids, such as VOR, are available to allow aircraft position determination; RNP APCH extraction required. |
| ADS-B | GNSS | RNP | GNSS core constellation (+DME/DME reversion) | Loss of surveillance but navigation possible along ATS route though RNP APCH missed approach procedures are required; unacceptable in EUR high density airspace operations but may be acceptable in low density. |

| Surveillance Position | | Navigation Position for RNP routes | | Effects if GNSS lost |
|---|---|---|---|---|
| MLAT | Independent | RNP | GNSS core constellation | MLAT systems may depend on GNSS as source of time synchronisation; in case of GNSS outage[17], these systems should continue to work nominally. In case of full GNSS outage, they should work in a reversion mode (full performance) for a certain time, and afterwards in a degraded mode (reduced performance); these modes of operation should be notified to the users of the outputs.<br>Some MLAT systems have their own mechanism of synchronisation and do not rely on GPS as a source of synchronisation.<br>This is also true for any surveillance sensors which use in general GNSS as the source of time for time-stamping their outputs; still, they may have as a back-up an internal time source with appropriate performance to maintain an accurate time-stamping for a given duration. |

For the above reasons in accordance with the generic safety analysis that were performed for European PBN airspace concepts, whether an RNAV or RNP specifications, the underlying assumption was either independent or cooperative independent surveillance.

Noting that the spacing of proximate routes is a function of many factors, studies have shown that with RNP 1 performance the availability of independent or cooperative independent surveillance becomes more critical than with the existing B-RNAV (RNAV 5) implementation. The RNP specification, with the addition of RF and FRT functionality, will permit route spacing between 5–7 NM on straight and turning segments. As such, a loss of surveillance and navigation could result in a catastrophic accident.

A variety of techniques can be used to determine the placement and spacing of proximate ATS routes. In some cases, there is a 2D strategic deconfliction where the 3rd dimension (vertical) is managed by the controller, and in other cases there is virtually a 3D strategic deconfliction where the spacing considers aircraft on proximate routes to be at the same flight level.

**AMC1 AUR.PBN.2015 Performance and functionality**

1. Approach procedures, SIDs/STARs and ATS routes should be predicated on the GNSS as the navigation position source and conform to the following:

    (a) ICAO Annex 4, 'Aeronautical Charts', 2009, 11th Edition, Amendment 58;

[17] GNSS timing (with accuracy better than 10 ns) only requires the acquisition of one satellite and not four4 for positioning. So, GNSS may remain a reliable source of time whereas it is no longer a reliable source of position information.

(b) ICAO Annex 11, 'Air Traffic Services', 2001, 13th Edition, Amendment 49;

(c) ICAO Document 9992 AN/494, 'Manual on the Use of PBN in Airspace Design', 2013, 1st Edition;

(d) ICAO Document 8168 OPS/611 'Procedures for Air Navigation Services: Aircraft Operations' (PANS-OPS), Volume I, 2006, 5th Edition, Amendment 6;

(e) ICAO Document 8168 OPS/611 'Procedures for Air Navigation Services: Aircraft Operations' (PANS-OPS), Volume II, 2014, 6th Edition;

(f) ICAO Document 4444 ATM/501, 'Procedures for Air Navigation Services: Air Traffic Management' (PANS-ATM), 2007, 15th Edition, Amendment 6;

(g) ICAO Document 9426 AN/924, 'Air Traffic Services Planning Manual', 1984, 1st Edition Amendment 4;

(h) ICAO Document 9905 AN/471 'Required Navigation Performance Authorization Required (RNP AR) Procedure Design Manual, 2009, 1st Edition;

(i) ICAO Document 9906 AN/472, 'Quality Assurance Manual for Flight Procedure Design', Volumes 1–6, 2009/2010/2012, 1st Edition, Amendment 1; and

(j) ICAO Document 9689 AN/953, 'Manual on Airspace Planning Methodology for determination of separation minima', 1998, 1st Edition, Amendment 1.

2. When implementing approach procedures with vertical guidance (APV), the published obstacle clearance altitude (OCA) should be such to permit operation of aircraft using either BARO-VNAV or SBAS vertical guidance.

3. For additional environmental efficiency, consideration should also be given to designing SIDs/STARs to conform to the following:

(a) ICAO Document 9931 AN/476, 'Continuous Descent Operations (CDO) Manual', 2010, 1st Edition; and

(b) ICAO Document 9993 AN/495, 'Continuous Climb Operations (CCO) Manual', 2013, 1st Edition.

4. Approach procedures, SIDs/STARs and ATS routes should be such that aircraft qualified in accordance with the applicable certification requirements corresponding with the performance and functionality specified in ICAO Document 9613 AN/937 — 'Performance-based Navigation (PBN) Manual', 2013, 4th Edition, as follows, are capable of the desired operations.

(a) VOLUME II — IMPLEMENTING RNAV AND RNP OPERATIONS, PART C — IMPLEMENTING RNP OPERATIONS, Chapter 5 — Implementing RNP APCH, Section A — RNP APCH operations down to LNAV and LNAV/VNAV minima, 5.3 NAVIGATION SPECIFICATION, 5.3.3 Aircraft requirements;

(b) VOLUME II — IMPLEMENTING RNAV AND RNP OPERATIONS, PART C — IMPLEMENTING RNP OPERATIONS, Chapter 5 — Implementing RNP APCH, Section B — RNP APCH operations down to LP and LPV minima, 5.3 NAVIGATION SPECIFICATION, 5.3.3 Aircraft requirements;

(c) VOLUME II — IMPLEMENTING RNAV AND RNP OPERATIONS, PART C — IMPLEMENTING RNP OPERATIONS, Chapter 3 — Implementing RNP 1, 3.3 NAVIGATION SPECIFICATION, 3.3.3 Aircraft requirements;

(d) VOLUME II — IMPLEMENTING RNAV AND RNP OPERATIONS, PART C — IMPLEMENTING RNP OPERATIONS, Appendix 1 to Part C — RADIUS TO FIX (RF) PATH TERMINATOR, 4. AIRCRAFT REQUIREMENTS;

(e) VOLUME II — IMPLEMENTING RNAV AND RNP OPERATIONS, Attachments to Volume II, Attachment A — BAROMETRIC VNAV (BARO-VNAV), 4. NAVIGATION SPECIFICATION, 4.7 Continuity of function, 4.7.2.1.2 (ability to meet the following altitude constraints: 'AT OR ABOVE' 'AT OR BELOW', 'AT','WINDOW');

(f) VOLUME II — IMPLEMENTING RNAV AND RNP OPERATIONS, PART C — IMPLEMENTING RNP OPERATIONS, Chapter 4 — Implementing Advanced RNP (A-RNP), 4.3 Navigation specification, 4.3.3 Aircraft requirements; and

(g) VOLUME II — IMPLEMENTING RNAV AND RNP OPERATIONS, PART C — IMPLEMENTING RNP OPERATIONS, Appendix 2 to Part C — FIXED RADIUS TRANSITION (FRT), 3. AIRCRAFT REQUIREMENTS.

**AMC1 AUR.PBN. 2020 Contingency**

Contingency procedures appropriate to the complexity of the airspace structure should be defined and implemented by ATS providers in the event of a degradation of navigation capability resulting from such items as outage of the GNSS core constellation or navigation failures of individual aircraft.

For procedures envisaged in AUR.PBN.2005(1) and AUR.PBN.2005(2), Air Traffic Service Providers and aerodrome operators should ensure that adequate missed approach procedures are provided for any envisaged degradation of navigation capability.

For Standard Instrument Departures and Standard Arrival Routes and ATS Routes, using PBN envisaged in AUR.PBN.2005 (3) or AUR.PBN.2005 (4), Air Traffic Service Providers and aerodrome operators should provide the adequate Navaid infrastructure for suitably equipped aircraft to enable these aircraft to continue meeting the performance requirements described either in AUR.PBN.2015 (3)(a) or AUR.PBN.2015 (4)(a)(i), (4)(b)(i).

In those instances where aircraft are unable to maintain the performance requirements described in AUR.PBN.2015 (3)(a) or AUR.PBN.2015 (4)(a)(i), (4)(b)(i), Air Traffic Service Providers should provide a vectoring service using ATS Surveillance based on independent or cooperative independent surveillance. In the absence of independent or cooperative independent surveillance, reversion to procedural control in the event of GNSS core constellation outage could be envisaged when the operating environment so permits.

**AMC1 AUR.PBN. 3005 Mixed operations**

The air traffic service provider should ensure that the air traffic controllers are capable of assigning appropriate and feasible clearances to aircraft. This may require that the aircraft capablity is conveyed to the air traffic controller.

**GM AUR.PBN. 3005 Mixed operations**

Mixed operations are characterised by:

(i) a combination of non-PBN and PBN applications within the same airspace; and

(ii) a combination of different PBN applications within the same airspace.

Mixed operations envisaged in (i) can either include different final approach procedures using ILS and/or GL, or those procedures envisaged in AUR.PBN.2015 (1), or PBN and non-PBN routes envisaged in AUR. PBN.2005(3) or (4).

# 4. Regulatory Impact Assessment (RIA)

## 4.1. Issues to be addressed

Each Member State, ATM/ANS provider or aerodrome operator implementing airspace/procedure design on the basis of a PBN specification or functionality of their choice would lead to a fragmented, disharmonised, inefficient and unsafe PBN implementation in the European airspace. It is, therefore, necessary to harmonise the PBN implementation in Europe by reducing/limiting the number of options that may be applied.

In order to ensure an efficient and safe implementation of performance-based navigation (PBN) in Europe, that enables performance improvement of the European Air Traffic Management Network (EATMN), the harmonised use of PBN specifications and functionalities is critical. The efficient and safe use of the European ATS route network and the efficient and safe access to European aerodromes are ensured if based on a uniform application of standardised PBN specifications and functionalities.

In addition, ICAO Assembly Resolution 37-11 calls for an 'implementation of approach procedures with vertical guidance (APV) (Baro-VNAV and/or augmented GNSS), including LNAV-only minima, for all instrument runway ends, either as the primary approach or as a back-up for precision approaches …', hence, regulatory measures are required to achieve the safety and operational benefits associated with this implementation. Therefore, the proposed regulation addresses all instrument runway ends (IRE) where there is only a non-precision approach procedure in place, and mandates the implementation of approach procedure with vertical guidance (APV) (3D PBN approach procedure). The implementation of APV at 24 European aerodromes is addressed within Regulation (EU) No 716/2014 (hereinafter referred to as the 'Pilot Common Project Regulation'). The implementation of APV as back-up for precision approach (Type A or Type B) at other European aerodromes is left voluntary on the basis of local performance objectives.

### *4.1.1. Background*

For the purpose of this RIA, the following should be noted:

(a) 3D approach (or precision approach (PA)) is a final approach with both lateral and vertical guidance. There are 2 types of 3D approaches:

(1) 3D approach where the final approach is performed using ILS, MLS, GLS or SBAS-CAT I (Type A and Type B); and

(2) 3D approach (or approach with vertical guidance – APV) including APV Baro-VNAV and APV SBAS (Type A).

(b) 2D approach (or non-precision approach – NPA) is a final approach with lateral guidance only. There are 2 types of 2D approaches:

(1) 2D conventional approach where the final approach is performed using DME, VOR and/or NDB ground Navaids only; and

(2) 2D PBN approach (or PBN approach with Lateral Navigation – LNAV only).

 

### *4.1.2. Safety risk assessment*

Final Approach

In the framework of the Runway Safety Initiative, many studies have been conducted[18]. In particular, the analysis of the 'Controlled Flight into Terrain' (CFIT) and 'Runway Excursions' have provided indications of the need for operational improvements to be implemented in order to reduce the frequency of those types of safety occurrences.

Non-precision approach procedures used to be performed as a series of descending steps conforming to the minimum published altitudes. The historical data on the accident/incident report has highlighted that these procedures are involved in a significant number of CFIT reports, as stated by the Flight Safety Foundation Approach and Landing Accident Reduction (ALAR) Task Force[19].

Historical data included in IATA Safety Report 2013[20] and covering the period 2009-2013 shows that runway excursion represents 23% of all the runway accidents.

The Agency in its 'European Aviation Safety Plan 2014-2017'[21] (EASP) states:

*'Between 1991 and 2010, EASA Member State operators had on average close to 1 fatality per year due to runway excursions at landing. The number of these occurrences has increased in line with the growth in traffic. As aviation traffic is expected to continue to grow worldwide as well as in Europe (albeit at a lower rate), the number of runway excursions can also be expected to increase further.*

*According to IATA's 2009 Safety Report, runway excursions represented 25% of all the events that occurred in 2008 and it is notable that the rate of reported accidents and serious incidents involving runway excursions has increased during the last decade. Statistically, around 80% of the occurrences happen during landing and 20% during the take-off phase.*

*Flying an unstabilised approach, landing too fast, too far down the runway, or conducting an extended flare, delayed or incorrect flight crew action on braking systems, late or no decision to abort landing, are identified as contributing factors to those accidents.'*

Several analysis and studies conducted on the implementation of the PBN approach procedures with vertical guidance have demonstrated that these procedures:

— by providing more accurate lateral guidance and accurate vertical guidance, can contribute significantly to the reduction of the number of CFIT;

— by providing accurate vertical guidance, can reduce significantly the number of unstabilised approaches which are one of the main root causes of runway excursions; and

— provide better crew awareness when approach operations are being conducted compared to approaches relying on guidance based on conventional Navaids (DME, VOR and/or NDB).

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18 See in particular 'Reducing the Risk of Runway Excursions' Report of the Runway Safety Initiative under https://www.easa.europa.eu/essi/documents/R3Efinal.pdf

19 See in particular http://www.skybrary.aero/bookshelf/books/856.pdf
and more generally http://www.skybrary.aero/index.php/Flight_Safety_Foundation_ALAR_Toolkit

20 See http://www.iata.org/publications/Documents/iata-safety-report-2013.pdf

21 See http://www.easa.europa.eu/system/files/dfu/sms-docs-European-Aviation-Safety-Plan-(2014-2017).pdf

SIDs and STARs

Currently, the structure of conventional SIDs and STARs is dependent on the positioning of the underlying ground Navaids. These Navaids imply constraints for the arriving and departing flights which may generate conflicts between them. Such situations, in busy TMA, require significant ATCO workload to tactically deconflict, laterally and/or vertically, incoming and outgoing traffic.

### 4.1.3. *Who is affected?*

The affected stakeholders are:

— Air Traffic Service Providers (ATSPs) or aerodrome operators who will have to ensure the design and implement the mandated PBN approach procedures at all instrument runway ends where only a non-precision approach procedure is currently in place;

— Air Traffic Service Providers (ATSPs) when they are required to implement PBN SIDs/STARs in order to meet performance objectives; and

— Air Traffic Service Providers (ATSPs) in coordination with the Network Manager when they are required to implement PBN ATS routes in order to meet performance objectives.

The following stakeholders will be indirectly affected by the rule:

— competent authorities, who will have to approve the safety assessment associated with the new PBN routes and procedures;

— Member States, who will have to publish the new PBN routes and procedures in their national AIP;

— the Network Manager, who will have to coordinate the future implementations and deployments of the new PBN routes and procedures to ensure connectivity between the ATS route network and the SIDs and STARs and a consistent evolution of the European Route Network (ERN) in line with the latest versions of its Network Operation Plan, Network Strategy Plan and Network Performance Plan; and

— airspace users, who wish to fly the published PBN routes and procedures and will have to ensure that their aircraft flight crews are qualified in order to be able to fly them on the basis of the published AIPs.

### 4.1.4. *How could the issue/problem evolve?*

The implementation of PBN in Europe has already started, essentially for approaches. If no regulatory provisions are put in place at this stage, there is a risk that various airspace designs will proliferate based on different PBN specifications resulting in potential connectivity issues and a disharmonised implementation. This would lead to safety and efficiency concerns and would impair the achievement of the essential requirement of seamless operations[22] within the single European sky.

[22] Regulation (EC) No 552/2004 of the European Parliament and of the Council of 10 March 2004 on the interoperability of the European Air Traffic Management network (the interoperability Regulation) (OJ L 96, 31.3.2004, p. 26).

Furthermore, since the publication by the Network Manager of the first edition of the Network Operations Plan[23] (covering 2012-2014) in March 2012 and up to the latest edition (covering 2014-2018/2019) in March 2014, airspace redesign based on RNP navigation specifications is identified as a key enabler to reach future performance objectives in terms of efficiency (mainly in en route airspace), in terms of environment (mainly in terminal airspace) as well as in terms of safety (mainly in final approach). Without harmonising the PBN specifications to be used, the maximum performance improvement of implementing PBN will not be achieved and the implemented solution would be suboptimal.

The information collected in the EUROCONTROL PBN Approach Map Tool indicates that in the 28 EU Member States plus the four EFTA countries (Norway, Iceland, Switzerland and Liechtenstein) at the end of 2013:

— 501 of the instrument runway ends (IRE) out of 1291, recorded in the PBN map tool, have no precision or PBN approach procedure;

— 790 IREs have no precision approach procedure, of which:

- 104 have currently an APV procedure and a non-precision PBN approach procedure in place;
- 287 have plans for the implementation of a APV procedure in the short term (before 2024).

The number of runway ends which have an APV procedures are as follow:

— 605 IREs with a precisiosn or APV approach in 2013 (47% of the total);

— 892 IREs with a precision or APV approach or implementation plan for a APV approach before 2024 (69% of the total).

The instrument runway ends **without** precision or APV approach procedures are as follows:

— 399[24] runway ends had at the end of 2013 no plans to implement an APV approach in the short term (before 2024).

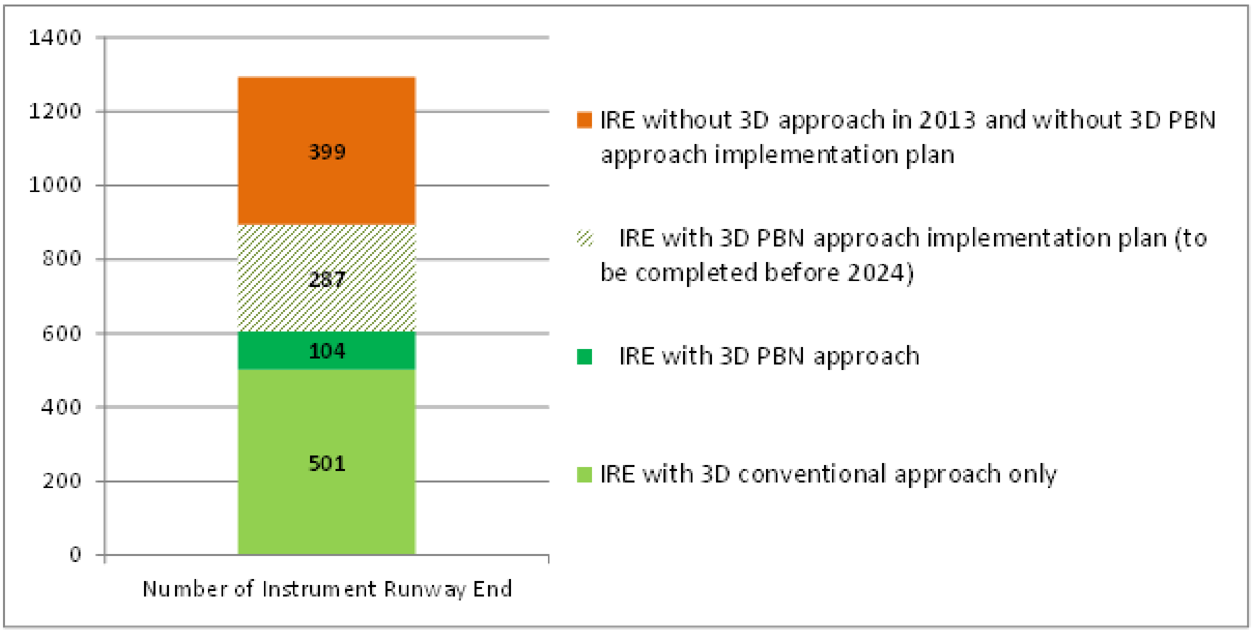
— However, if plans are not maintained, the number of instrument runway ends with no precision approach procedure in place would be 686[25]. This is considered as a very extreme scenario due to the fact that the number of runway ends with implementation plans before 2024 follows the current trends of 3D PBN approach procedures currently implemented in the EASA Member States.

[23] The successive editions of the Network Operation Plan are available under http://www.eurocontrol.int/articles/operations-performance-planning at the bottom of the page when clicking on the 'Library' tab.

[24] 1291 total IRE minus 605 runway ends without 3D conventional approach procedure, minus 287 runway ends with implementation plans for 3D PBN approach procedure.

[25] 399 runway ends without plans plus 287 with plans.

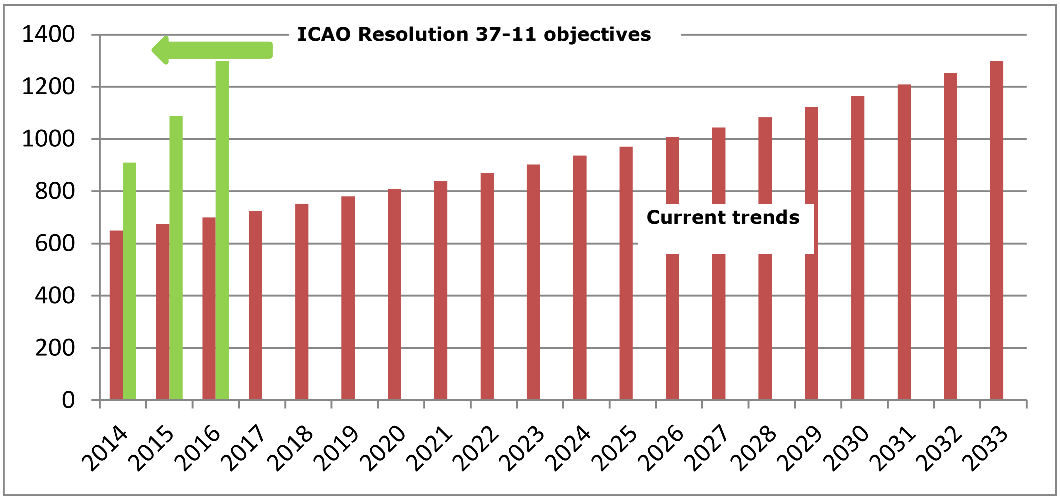
**Figure 5 — APV (3D PBN approach) implementation status for EASA Member States in 2013**




If the rates of the different 3D approach types implementation observed over the last 3 years were to continue unchanged, one can extrapolate that all instrument runway ends in EU 28 + 4 would be covered by a 3D approach (PBN or conventional) by 2033.

The ICAO Assembly resolution 37-11[26] creates a strong commitment for the full implementation of RNP approaches by 2016 with an intermediate objective of 70 % implementation by the end of 2014 which is not being achieved. Therefore, if no regulatory provision is put in place, the rate of implementation of RNP approaches will remain far behind of the schedule recommended by the ICAO Assembly resolution 37-11.

**Figure 6 — APV implementation at runway ends: current trends vs ICAO objectives**




[26] http://www.icao.int/safety/pbn/PBN%20references/Assembly%20Resolution%2037-11_%20PBN%20global%20goals.pdf

## 4.2. Objectives

The overall objective of the EASA system, as required by Article 2(1) of the Basic Regulation, is to establish and maintain a high uniform level of civil aviation safety in Europe.

In addition thereto, the relevant overall objectives of this rulemaking task are the following:

— to promote cost-efficiency in the regulatory and certification processes;

— to assist Member States in regulatory coordination with third countries and international organisations and harmonisation with the Chicago Convention and, in particular, ICAO resolution A37-11; and

— to provide a level playing field for all actors in the internal aviation market.

The specific objectives of this task are:

— to ensure the safe, efficient and harmonised implementation of specific PBN specifications and functionalities in the EATMN;

— to improve safety at all European aerodromes;

— to increase flight efficiency by enabling the design of PBN based SIDs/STARS and ATS routes in Europe in accordance with the most flight-efficient PBN specifications;

— to implement proportionate PBN requirements for operators of aircraft for which the retrofit costs would be disproportionate compared to the expected benefits;

— to prevent a disharmonised implementation of PBN in Europe; and

— to minimise airspace connectivity issues.

The specific applicable constraint of this task is to be compatible with the PBN regulatory provisions already included in the Pilot Common Project Regulation, and more specifically in ATM Function 1 (AF1), which is further described in the Annex of the Regulation.

## 4.3. Policy options

Option 0

The 'Baseline' option 0 is to be considered as the reference scenario where no further regulatory measures are taken regarding PBN implementation in Europe.

The implementation of PBN will take place where and when this implementation permits individual ATSPs, aerdrome operators or the Network Manager to achieve its performance objectives either derived from the European performance scheme or from individual business decisions.

As such, the implementation will be on a pure voluntary basis. It may happen that some parts of the European airspace would no longer be accessible (in the short term or after a transition period) to aircraft that would not have the locally required PBN performance and functionality.

Furthermore, it holds the risk of a delayed implementation in Europe of the ICAO Assembly Resolution 37-11 and of a disharmonised implementation of PBN specifications in the EATMN.

<u>Option 1</u>

The 'Harmonised PBN implementation' Option 1 aims at ensuring a safer and more efficient implementation of PBN in Europe by accelerating the implementation of APV approach procedures where there are only non-precision approaches in place and by enabling a harmonised PBN implementation in general. Option 1 consists in 2 types of measures:

— mandatory requirements in the field of PBN approach procedures for ATSPs or aerodrome operators; and

— non-mandatory requirements:

- only when ATSPs decide to implement PBN for SID and STARs ATS routes, they will have to follow specific requirements to ensure a progressive harmonised implementation;
- the operators have still the possibility to decide to use these PBN requirements or to continue with conventional ones.

Option 1 <u>**mandates**</u> the implementation of APV approach procedures at all instrument runway ends where there are only non-precision approach procedures available.

The 'Harmonised PBN implementation' Option 1 specifies that when ATSPs/aerodrome operators implement approach procedures using PBN, these procedures shall be based on aircraft having the following functionality and performance:

(a) performance outside the Final Approach Segment: the lateral TSE and the along-track error are within ±1 NM for at least 95 % of the total flight time;

(b) performance within the Final Approach Segment:

(1) the lateral TSE and the along-track error are within ±0.3 NM for at least 95 % of the total flight time (BARO VNAV);

(2) the vertical TSE is equal to or lower than 99.7 % of the time:

(i) 150 ft (at altitude equal to or lower than 5000 ft);

(ii) 200 ft. (at other altitudes);

or

(3) the angular lateral and vertical performance shall be equivalent to 1 and 2 respectively;

(c) functionalities:

(1) on-board performance monitoring and alerting;

(2) ability to meet altitude constraints, i.e. 'AT', 'AT OR ABOVE', 'AT OR BELOW', 'WINDOWS' (VNAV function).

The 'Harmonised PBN implementation' Option 1 specifies that, <u>**when**</u> ATSPs implement SIDs and STARs using PBN, it shall be based on aircraft having the following functionality and performance:

(a) performance outside the Final Approach Segment: the lateral TSE and the along-track error is within ±1 NM for at least 95 % of the total flight time;

(b) functionalities:

(1) on-board performance monitoring and alerting;

(2) RF leg;

(3) RNAV Holding; and

(4) ability to meet altitude constraints, i.e. 'AT', 'AT OR ABOVE', 'AT OR BELOW', 'WINDOWS'.

The 'Harmonised PBN implementation' Option 1 specifies that **when** ATS Routes are implemented using PBN, they shall be based on aircraft having the following functionality and performance:

(a) below FL 195:

(1) performance: the lateral TSE and the along-track error are within ±1 NM for at least 95 % of the total flight time;

(2) functionality:

(i) RNAV Holding;

(ii) on-board performance monitoring and alerting;

(b) above FL 195:

(1) performance: the lateral TSE and the along-track error is within ±1 NM for at least 95 % of the total flight time.1;

(2) functionality:

(i) FRT;

(ii) on-board performance monitoring and alerting.

It should be noted that the aircraft performance and functionality associated with the design of SID/STARs is identical to those specified in the PCP IR. This regulation already mandates the implementation of PBN SID/STARs by the end of 2023, designed in accordance with the functionality and performance described above, in 22 aerodromes of the EU Member States and 2 further aerodromes in Switzerland and Norway. The PCP IR also mandates the implementation of APV at these aerodromes . Therefore, the 'Harmonised PBN implementation' Option 1 is consistent with the PCP IR and requires the implementation of RNP approach procedures at other aerodromes; it also requires the ATSPs to design other PBN SIDs and STARs on the basis of the same aircraft functionalities.

Option 1 provides a rationale as to where and when harmonised PBN ATS routes or procedure implementation should take place by linking these implementations by ATSPs in coordination with the Network Manager with the need to meet performance objectives.

No direct obligation has been applied to aircraft operators to equip with any specific PBN specifications, as this is already addressed in the existing regulations. The requirements are set out in Regulation (EU) No 965/2012:

'ORO.GEN.110 Operator responsibilities

(…)

(d) The operator shall ensure that its aircraft are equipped and its crews are qualified as required for the area and type of operation.

(…)'

and Regulation (EU) No 923/2012:

'SERA.5015 Instrument flight rules (IFR) — Rules applicable to all IFR flights:

(a) Aircraft equipment

Aircraft shall be equipped with suitable instruments and with navigation equipment appropriate to the route to be flown and in accordance with the applicable air operations legislation.'

Therefore, in order to fly PBN routes and procedures, aircraft have to be equipped appropriately, i.e. hold an Airworthiness Type Certificate corresponding to the performance and functionality described under the relevant bullets of AUR.PBN.2015.

Within Option 1, non-PBN equipped aircraft will still be able to fly alternative non-PBN routes or procedures due to the requirement that ATSPs, aerodrome operators and the Network Manager, in parallel to their PBN implementation, shall continue to support non-PBN operations with limitations/constraints (cf. AUR.PBN.3005 — Mix operations). The availability of non-PBN routes and procedures as alternative to the new PBN routes and procedures may not be guaranteed in the case of Option 0.

This option enables the airspace users to operate aircraft having the capabilities to fly these new PBN routes and procedures when they have assessed a positive business case to do so or to operate their other aircraft (e.g. those which are expensive to retrofit or which are not yet retrofitted) to fly ATS routes and procedures where these capabilities are not needed.

This will also give time to airspace users to plan the progressive upgrade of their fleets in order to avoid potential bottlenecks due to shortage of upgrade slots at the airframe manufacturers or at an approved Design Organisation or due to shortage of relevant equipment at avionics manufacturers.

**Table 2: Instrument runway ends development scenarios**

| *Type of instrument runway ends (IRE)* | *Value* | *Comments* |
|---|---|---|
| **Total number of instrument runway ends (IRE) (EASA MS)** | 1291 | |
| **Status end of 2013:** | | |
| IRE with precision approach only | 501 | These IRE are already compliant with Option 1 |
| IRE without precision approach | 790 | IRE to be considered for the study |
| of which: | | |
| IRE with APV approach | 104 | These IRE are already compliant with Option 1 |
| IRE with APV approach implementation plan (to be completed before 2024) | 287 | |

| | | |
|---|---|---|
| **Baseline scenario** | | |
| IRE with precision or APV approach in 2013 | 605 | These IRE are already compliant with Option 1 |
| IRE with precision or PBN approach in 2013 or APV approach implementation plan before 2024 | 892 | These IRE will be compliant with Option 1 in time |
| **Option 1: implementation of IRE with the need to implement APV approach** | | |
| IRE without precision approches in 2013 and without an APV approach implementation plan | 399 | Scenario 1: most probable scenario |
| IRE without precision approach at the end of 2013 and if current implementation plans are not fulfilled | 686 | Scenario 2: extreme scenario |

The most probable scenario is that Option 1 will be implemented over 399 IREs before 2024. The extreme scenario may consider 686 maximum IREs in the scope of Option 1 if current implementation plans are not maintained. However, this is considered as a very extreme scenario due to the fact that the number of runway ends with implementation plans before 2024 follows the current trends of APV currently implemented in EASA Member States. Therefore, only the most probable will be assessed in the impact analysis section. The impacts related to the extreme scenario are to be found in Appendix 3. Please note that the global outcome of the extreme scenario is in line with the most probable scenario.

**Table 3: Selected policy options**

| *Option No* | *Short title* | **Description** |
|---|---|---|
| 0 | Do nothing | Baseline option (no change in rules; risks remain as outlined in the issue analysis). |
| 1 | Harmonised PBN implementation | Proposed regulation mandates implementation by 2024 of APV at all instrument runway ends where there is no precision procedure in place and ensures harmonised PBN implementation in Europe where and when needed to reach performance criteria. |

## 4.4. Methodology and data

### *4.4.1. Applied methodology*

A multi-criteria analysis methodology has been carried out allowing the comparison of both options by scoring them against different criteria, comprising impacts such as safety, economic, etc., as shown below.

The term ‘multi-criteria analysis’ (MCA) covers a wide range of techniques that share the aim of combining a range of positive and negative impacts into a single framework to allow easier comparison of scenarios. Essentially, it supplements the cost-benefit analysis in cases where there is a need to present impacts which contain qualitative, quantitative and monetary data, and where there are varying degrees of certainty.

The objective of this rulemaking activity has been outlined in Chapter 4.2. The options have been described above and will be analysed in the following chapter with respect to each of the assessment areas. The criteria (i.e. type of impacts) used to compare the options were derived from the Basic Regulation and the guidelines for the Regulatory Impact Assessment were developed by the European Commission[27]:

(a) safety impact;

(b) environmental impact;

(c) social impact;

(d) economic impact;

(e) proportionality issues; and

(f) 'Better regulation' and harmonisation.

The impacts have been assessed by adopting an easy and intuitive scoring approach to indicate the potential outcome of an option regarding a specific impact:

(a) +: positive impact;

(b) 0: neutral impact; and

(c) –: negative impact.

For instance, 0 to + means that the impact will be between 0 and the maximum estimated value and will depend on the conditions of implementation (where, when, how, …).

In addition, the economic impacts have been substantiated by a detailed cost-benefit analysis for the mandatory part of Option 1.

### *4.4.2. Data collection*

Data was collected from the EUROCONTROL PBN Approach Map Tool (monitoring the status and plans of PBN approach implementations' deployment). This information has been collected via different channels including reports to ICAO and RAiSG (the EUROCONTROL RNAV Approach implementation Support Group). Moreover, the implementation status captured in the PBN Approach Map Tool is checked against actual publications. It currently contains the implementation status of 1291 runway ends in the 28 EU Member States plus the four EFTA countries (Norway, Iceland, Switzerland and Liechtenstein) and corresponds to 665 aerodromes. These figures are derived from voluntary reporting with the data coming from 31 states. 665 is a figure very close to 589, which is the number of aerodromes reported to follow the European common rules on aerodrome certification (Regulation (EU) No 139/2014). The figures extracted from the PBN Approach Map Tool are deemed sufficiently reliable to be used in this Regulatory Impact Assessment.

[27] http://ec.europa.eu/governance/impact/commission_guidelines/commission_guidelines_en.htm

In addition, the information on the current implementation status of the runway ends, studied in the document 'RNAV Approach Benefits Analysis — Final Report[28] (20 May 2009), was collected on the basis of the officially published approach procedures.

## 4.5. Analysis of impacts

### *4.5.1. Safety impact*

Whatever option would be selected, the implementation of RNP routes and procedures, with or without vertical guidance, relies on the availability of position information provided by a GNSS sensor on board the aircraft. Therefore, in case the ground surveillance is solely based on ADS-B, which also relies on information provided by a GNSS airborne sensor and the underlying GNSS constellation(s), this will become a single point of failure between the ground surveillance system and the airborne area navigation system, rendering the reversion to aircraft surveillance vectoring unusable. Therefore, this risk is mitigated by the application of Option 1 through the provisions described in AUR.PBN.2010 Surveillance and communications (global GNSS failure) and AUR.PBN.2020 Contingency (GNSS receiver failure on board an aircraft).

#### *4.5.1.1 Final Approach Operations*

Safety benefits of implementing PBN approach procedures

**The introduction of APV procedures will allow harmonisation of the approach types, a better separation from obstacles and an improved pilot situational awareness compared to non-precisiosn approach procedures.**

APV approach procedures will contribute to the reduction of the risk of CFIT by providing greater systematic accurate lateral and vertical guidance than in non-precision approach procedures.

APV approach procedures will facilitate stabilised final approach operations with a continuous vertical profile defined in the procedure. This will decrease the risk of runway excursions due to unstabilised approach**.**

However, some safety issues have to be considered:

— It must be highlighted that according to the current Agency AMC for RNP APCH (AMC 20-27), the distance from the next way point is displayed to the pilot. It is foreseen that this functional capability will be maintained when the airworthiness part of AMC 20-27 is migrated into the forthcoming update of the CS-ACNS addressing the Navigation Subpart.

— The runway threshold may not be displayed to the pilot in the cases where intermediate fixes (e.g. step down) are coded in the navigation database. This may increase the workload of the flight crew. It is foreseen that this aspect will be incorporated in the forthcoming update of the CS-ACNS.

[28] http://www.eurocontrol.int/sites/default/files/content/documents/navigation/p723D003-business-case-final-report-v2-1.pdf

— Another safety issue may rise from the type of missed approach defined for the RNP approach procedure. Indeed, if both the approach and the missed approach procedures are based on GNSS, a GNSS failure becomes a common mode of failure for these two segments of the flight. Should it be the case, this should be carefully studied in the frame of the associated safety case, and appropriate mitigation measures should be defined.

Option 0

In the context of Option 0, these safety benefits may be delayed up to 2033.

Option 1

Option 1 will ensure that these safety benefits will be achieved by 2024.

#### *4.5.1.2 Operations within SIDs and STARs*

Safety benefits of implementing PBN to design SIDs and STARS

The PBN aircraft performance and capabilities on the basis of which SIDs and STARs will be designed will lead to a significant improvement in operations, including a better adherence to the ATS route centreline in turns, allowing the reduction of the route spacing on straight line segments as well as on around turns. Moreover, the introduction of VNAV will increase the predictability of the vertical profiles and will allow strategic deconflicting of the routes. The introduction of the PBN SIDs and STARs will potentially allow the complete deconflicting of the arrival and departure traffic flow, increasing the capacity in the terminal area whilst maintaining an acceptable level of safety. The coding of the vertical profile in the Flight Management System (FMS) will result in a reduction of the pilot workload and an improvement of the consistency of the way the routes are flown.

As this will imply a reduction of the aircrew workload and, to a certain extent, of the ATCO workload as well, it will have a positive impact on the safety of the operations being conducted.

On the other hand, the safe implementation of these functions on board the aircraft will be highly dependent on the quality of the airborne database; therefore, a high level of data accuracy and integrity of these databases must be ensured in order to guarantee a safe operation.

In this RIA, it is assumed that the implementation of the outcome of the Agency rulemaking task RMT.0477 (‘Technical requirements and operational procedures for aeronautical information services (AIS) and aeronautical information management (AIM)’) will ensure the required level of data integrity and accuracy needed, allowing a safe implementation of PBN SIDs and STARs procedures and routes.

Option 0

In the context of Option 0, these safety benefits may be achieved if the selected PBN functionality and performance are the same as those required in the draft IR. However, the safety impact will be negligible if another set of PBN functionality and performance (e.g. RNAV 1) is only selected.

Option 1

Option 1 will ensure that the safety benefits described above will be provided when PBN SIDs and STARs are designed in accordance with the required PBN functionality and performance.

#### *4.5.1.3 Overall safety impact*

In all, Option 1 has greater or earlier safety benefits than Option 0.

**Table 4: Overall Safety impact**

| Areas of applicability | Option 0 | Option 1 |
|---|---|---|
| Final Approach | 0 | + |
| SID/STAR | 0 to + | + |
| ATS Route | N/A | N/A |

### *4.5.2. Environmental impact*

#### *4.5.2.1 Final Approach Operations*

<u>Environmental benefits of implementing RNP APCH in final approach</u>

Potential fuel burn savings may be available following the implementation of RNP APCH, due to lower approach minima which may result in a reduction of the number of missed approaches/diversions. According to an analysis of US databases by the Committee on Aviation Environmental Protection (CAEP), it has been estimated that the average additional fuel, used in the case of diversion from an aerodrome without a precision approach, is approximately 380-470 kg, and that diversions occur in approximately 0.5 % of the operations at such aerodromes.

In the case of the Guipavas and Oulu aerodromes[29], which are studied in the frame of the RNAV Approach Benefits Analysis – Final Report (20 May 2009), the corresponding environmental benefits, as indicated in Table 5 below and assuming a 380 kg fuel burn saving per avoided disruption (1 kg of fuel equals 3,15 kg of $CO_2$), would represent roughly 5 % of the estimated cost saving associated with the avoidance of the diversion costs.

**Table 5: Examples of environmental benefits**

| *Aerodromes* | *$CO_2$ saving (kg)* |
|---|---|
| Guipavas | 52 700 |
| Oulu | 7 200 |

<u>Option 0</u>

In the context of Option 0, these environmental benefits may be delayed up to 2033.

<u>Option 1</u>

In the context of Option 1, these environmental benefits will be achieved by 2024.

[29] These two aerodromes have been selected as they showed very similar traffic conditions (6 700 vs 4 800 landings) and a similar percentage of non-precision approach landing (15 % vs 21 %).

#### *4.5.2.2 Operations within SIDs and STARs*

Environmental benefits of implementing PBN in SIDs and STARs

Emerging CAEP studies estimate that lateral track reductions due to the implementation of PBN SIDs and STARs may result in fuel savings of 20 to 50 kg of fuel per aircraft and per arrival and 0 to 30 kg of fuel per aircraft and per departure[30/31].

**Table 6: PBN SIDs and STARs — CO2 savings**

| | *Average fuel saving per flight (kg)* | *Average $CO_2$ saving per flight (kg)* |
|---|---|---|
| PBN SID | 0–30 | 0–95 |
| PBN STAR | 20–50 | 60–160 |

Option 0

If the stakeholders are willing to implement PBN to achieve environmental benefits within SIDs and STARs, PBN will be applied voluntarily to achieve these benefits.

Option 1

The aircraft performance and functionality referenced in Option 1 for the design of PBN SIDs and STARS will enable the environmental benefits described above.

Therefore, Option 1 will provide the same environmental benefits as Option 0.

#### *4.5.2.3 Operations along ATS routes (En route or terminal operations)*

Environmental benefits of implementing PBN ATS routes

Designing PBN based ATS routes (e.g. based on a ±1 NM accuracy and FRT aircraft performance and functionality) provides the opportunity to design shorter and more direct ATS routes, thus achieving fuel savings.

Should there be capacity improvements to be achieved; designing PBN based ATS offers the opportunity to implement the smallest route separation minima, therefore combining the provision of higher capacity with maintaining ATS route lengths close to the optimum.

Option 0

If the stakeholders are willing to implement PBN ATS routes to achieve environmental benefits, PBN will be applied voluntarily to achieve these benefits.

Option 1

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30 These studies have not yet been approved by CAEP.

31 CCO (Continuous Climb Operations) and CDO (Continuous Descent Operations) can be enabled by PBN SIDs and STARs. However, it should be noted that PBN is not required to undertake a CCO or CDO; it is a facilitator of CCO and CDO only. ICAO-CAEP estimates that, on average, a CDO and CCO may save an additional 60 kg and 90 to 150 kg of fuel respectively. Also CCO and CDO may also provide noise benefits. EUROCONTROL estimates that CDO may reduce noise impact on the ground by around 1-5 dB per flight.

The aircraft performance and functionality referenced in Option 1 for the design of PBN ATS routes will enable the environmental benefits described above.

Therefore, Option 1 will provide the same environmental benefits as Option 0.

#### *4.5.2.4 Overall environmental impacts*

In all, both options have the same environmental benefits, although option 1 provides the benefits associated to the implementation of PBN approaches earlier.

**Table 7: Overall environmental impact**

| Areas of applicability | Option 0 | Option 1 |
|---|---|---|
| Final Approach | 0 to + | + |
| SID/STAR | 0 to + | 0 to + |
| ATS Route | 0 to + | 0 to + |

### 4.5.4. Social impact

No social impacts are expected from the application of the proposed regulatory provisions.

### 4.5.5. Economic impact

#### 4.5.5.1 Network perspective

Whilst implementing PBN in the EATMN in the context of option 0 provides a wide range of benefits as described above and below, it may induce airspace dis-harmonisation and airspace connectivity issues due to the potential implementation of dis-harmonised PBN specifications in different areas. These potential issues are the following:

— Airspace disharmonisation

- Should Option 0 be retained, when planning a flight across or within Europe, aircraft operators will have to verify that the aircraft and crew are qualified for the particular PBN specifications in order to be able to fly the ATS routes and procedures as planned. As a result of the variety of PBN specifications potentially required along the different routes and procedures, ensuring that aircraft and crew are qualified may become a tedious task with a potential risk of errors. This may lead to the allocation of a more performant aircraft to the flight whereas it is not justified in reality or the aircraft is not providing the required PBN functionality and performance, resulting in the flight being diverted to another destination/route which is not efficient.
- Through Option 1, depending on the flight an aircraft operator is planning to operate by combining some of the appropriate harmonised PBN specifications (but maximum 3 of them), the aircraft operator will be able to determine which aircraft and crew qualifications are required to perform that flight.

— Airspace connectivity

- Under Option 0, if PBN is implemented into two adjacent airspaces, but one relying on RNP1 and the other on RNP2 in order to achieve specific capacity objectives, then seamless connectivity will not be possible because the route spacing minima will not be the same for these two airspaces. Thus, leading to a decrease of capacity in the RNP1 airspace at the border with the RNP2 airspace or to the imposition of RNP1 performance and functionality in the RNP2 airspace just for managing smoothly the interconnection between RNP2 and RNP1.
- The consistent implementation of PBN proposed through Option 1 will ensure that no such network connectivity issue will occur, whereas Option 0 may lead to such connectivity issues which in turn may result in a reduction of expected benefits and/or in a slowdown in the implementation of PBN.

Therefore, the economic assessment of Option 0 starts by default with a certain negative score.

#### *4.5.5.2 Final Approach Operations*

##### *4.5.5.2.1 Benefits of RNP approach implementation (avoided flight diversions)*

The design of PBN approach procedures, in accordance with aircraft performance specified in AUR.PBN.2015 (1) (RNP APCH), has the potential to provide lower operating minima than the non-precision approach procedures. This will, therefore, increase the accessibility to instrument runway-ends by avoiding flight diversions where precision approach procedures currently do not exist. Moreover, the potential lower operating minima that can be established for APV approaches, compared to those for non-precisiosn PBN approach, render it a good alternative solution compared to a precision approach from an operational point of view.

The benefits of PBN approach implementation at these runway-ends are the following:

— aerodromes:
  - prevent the revenue losses caused by aircraft diversion from that aerodrome; and
  - ensure a better accessibility of the aerodrome;

— airspace users — prevent the additional costs caused by aircraft diversion.

*<u>Evaluations of benefits for airspace users associated with the smaller number of diversions from these aerodromes due to implementation of APV</u>*

The study that was carried out to investigate the benefit of APV approaches at a range of aerodromes within Europe (see footnote No 33) focussed upon the benefit of reduced approach operational minima, on the consequential reduction in disruptions (delays, diversions or cancellations) and on the resulting operational cost savings for airspace users. The cost savings were investigated by means of 16 case studies on aerodromes in Finland, France, the Netherlands, Norway, Switzerland and Ukraine. These aerodromes exhibited a variety of traffic levels, aircraft users, weather conditions, surrounding terrain and ILS capabilities. All the aerodromes studied have only one runway.

This study shows that benefits can be gained when a minimum percentage of the arrivals are currently performed using non-precision approach procedures. These cases correspond mainly to aerodromes where ILS is only available at one runway end, which is the most commonly used under usual weather conditions However, as the usual weather conditions are not present for a significant proportion of the cases, a number of approaches are performed using the non-ILS-equipped runway end and relying on a non-precision approach procedure.

Within the studied aerodromes, the benefits fell into three categories: negligible (when both runway ends are equipped with ILS), medium benefit (in the region of EUR 40 000 per year) and high benefit (in the region of EUR 200 000 per year). This difference between medium and high benefits was dependent upon a number of factors, including aerodrome traffic levels and the obstacles surrounding the runway (the potential reduction in operational minima enabled by RNP approach mainly depends on these obstacles); the local weather conditions are directly dependent on the proportion of disruption which can be potentially avoided by implementing an RNP approach procedure. In general, the combination of Baro with BAS (Scenario 2 in the study) provided an additional EUR 20 000 annual benefit per runway end in comparison with solely Baro irrespective of the potential benefits of Scenario 1 (Baro only).

For instance, in the cases of 2 studied Finnish aerodromes (Tempere and Rovaniemi), the benefits are rather low although the proportions of NPA arrivals are significant (between 10 and 20 %). Since the weather conditions are either very good or very bad, the reduction of decision height minima that the implementation of an APV approach would lead to was not sufficient to prevent the diversion of the flights in most of the cases. Therefore, the benefits remain in the medium range. For instance, for similar traffic conditions and a similar proportion of diverted flights in France (Brest/Guipavas), a high benefit would be gained.

As explained above, the potential benefits depend on of the weather conditions at each given aerodrome; it is, therefore difficult to classify them easily on that basis without knowing precisely their typical weather conditions. The EUR 4 660 used as an average in the study should be reviewed by a factor of 1 183 to reach the corresponding value in 2013. This gives an average value of EUR 5 515 for flight diversion costs in 2013.

These benefits were calculated on the basis of the Standard Inputs for EUROCONTROL Cost Benefit Analyses which were available in May 2009 (i.e. Edition 3.0 of that document updated to 2006 values). The EUR 4 660 used as an average in the RNAV Approach Benefits Analysis — Final Report (20 May 2009) should be reviewed by a factor of 1 183 to get the corresponding value in 2013. This gives an average value of EUR 5 515 for flight diversion costs in 2013.

As a conclusion based on this study, it should be noted that all runway ends[32] where there was no precision approach procedure in place in 2009, currently (2014) have either an APV approach procedure or a precision approach procedure in place, irrespective of the expected benefits identified in the study. This might be considered as indicative of the fact that the APV approach procedure has an overall beneficial impact on the aviation sector.

The following costs in the table below reflect the 2013 costs for flight diversion according to different flight categories.

**Table 8: EUROCONTROL currently recommended costs of diversion (financial year 2013)**

| *Type of flight* | *Cost of flight diverted[33] (EUR)* |
|---|---|
| Regional flights | 820–5 870 |
| Continental flights | 1 175–8 800 |
| Intercontinental flights | 5 870–64 600 |

The runway ends that are impacted by the application of Option 1 are very unlikely to be the destination of intercontinental flights. Therefore, the applicable figures should be in the range of 820 to EUR 8 800 per passenger flight.

It is to be noted that these runway ends are also used by business aviation for which no figures of the diversion cost are yet available.

[32] But the two runway ends in Ukraine (Simferopol and Kiev/Borispol)

[33] The above figures are for passenger flights only and do not take into consideration the penalties associated with the late delivery of cargo as this type of data is not yet readily available.

*Assessment of the accessibility improvement benefits at these aerodromes due to implementation of PBN approach*

This assessment has to be made on a case by case basis depending on the local environment as the actual accessibility improvements depend on the aerodrome infrastructure, its current or future capability to accommodate the potential additional traffic.

Taking into account the 10 runway ends studied (see footnote No 33) that have no APV approach (5 runway ends in France and 5 runway ends in Finland), an average operational benefit of EUR 92 101 per runway end and per year can be derived which is twice the cost of implementing an APV approach procedure. It consists of an average of 16.7 avoided diversions per runway end and per year multiplied by the monetary value of EUR 5 515 for a flight diversion. These benefits are achieved if the airlines operators implement the corresponding PBN requirements for aircrafts.

Following the implementation data of APV approach in Chapter 4.1.4, if current plans are maintained, approximately 399 instrument runway ends will directly be subject to the provisions of the regulation[34]. This would mean an overall maximum benefit for avoided diversions for the period 2014-2033 in EASA Member States of EUR 4 077 000 not discounted or EUR 236 000 000 discounted at 4%.

*Evaluation of aerodrome prevented revenue losses associated with the number of avoided diversions from these aerodromes due to implementation of PBN approach*

This aspect is assumed to be neutral at EATMN level, as the aerodrome charges will in any case be paid by the aircraft operator either at the original destination aerodrome or at the aerodrome to which the flight has been diverted.

Assessment at aerodrome level can only be made on the basis of the local conditions at that aerodrome.

#### *4.5.5.2.2 Cost of RNP approach implementation*

The average total cost of the development of a single new approach procedure for an ATSP/ aerodrome operator is assessed at approximately EUR 30 000. This cost includes:

— preparatory surveys;

— procedure design;

— procedure validation (including test flights);

— preparation and submission to the competent authority; and

— controller training.

Where two procedures are developed for the same runway end (e.g. based on BARO-VNAV and SBAS), the costs are estimated at EUR 47 500 .

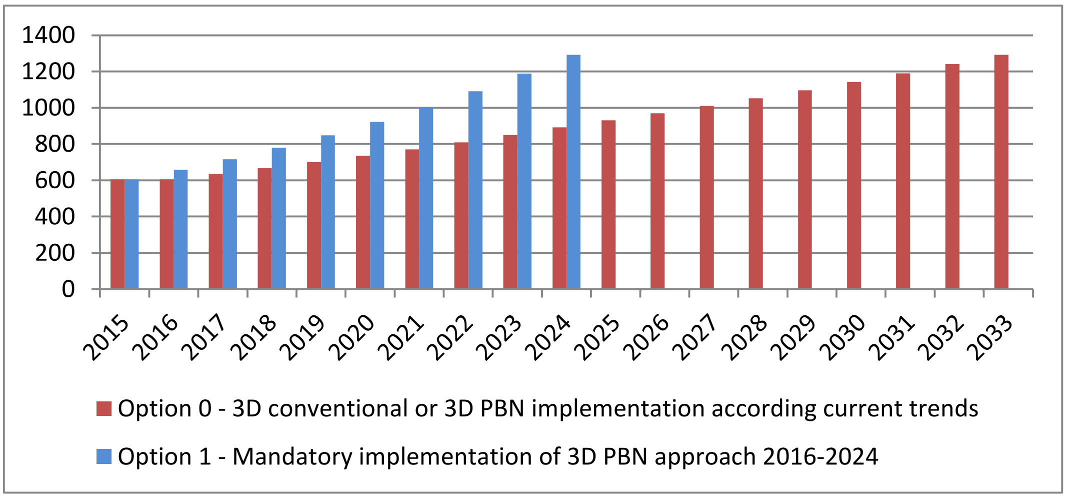
These values are averaged for Europe and it is recognised that there may be significant variations from state to state.

[34] However, if plans are not maintained, the number of instrument runway ends to which the regulation would be applicable is approximately 501: this is considered as a very extreme scenario due to the fact that the number of runway ends with implementation plans before 2024 follows the actual trends of 3D PBN approach procedures currently implemented in EASA Member States.

Following the implementation data of APV approach in Section 4.1.4, if current plans are maintained, approximately 399 instrument runway ends will directly be subject to the provisions of the regulation; however, if plans are not maintained, the number of instrument runway ends to which the regulation would be applicable is approximately 686.

The trends for Option 0 and Option 1 in terms of runway ends with 3D approach operations would be as follows:

**Figure 7 — Total runway ends with 3D approach operations: Option 0 versus Option 1**




The cost of developing new RNP approach procedures for all 399 runway ends without implementation plans in 2013 would be:

— EUR 12 000 000 not discounted at an average cost of EUR 30 000 per runway end (BARO or SBAS) for the ATSPs/aerodrome operators;

— EUR 19 000 000 not discounted at an average cost of EUR 47 500 per runway end (BARO and SBAS);

— EUR 9 000 000 to EUR 14 000 000 discounted at 4 %.

Note: For more details, see Appendix 2.

Adaptation of ATC supporting tools may be needed but this is not expected to involve incremental costs for the ANSPs.

**Cost impacts for other stakeholders**

The cost impact on aircraft operators is difficult to estimate due to several factors:

(a) the number of aircrafts qualified to benefit from the advantage of APV is unknown;

(b) 47% of the runway ends in EASA Member States have already APV or precision approach procedures (i.e. 605), which tends to indicate that there is already a significant aircraft population which is qualified or will be soon qualified to enjoy the benefits of such procedures;

(c) it is left to the choice of the aircraft operators to decide if it is economically feasible to qualify their aircraft in order to enjoy the benefits associated with their operation.

However, it is not expected that the impacts would be significant based on (b) and (c) above.

The implementation of a new approach final procedure will impose an additional workload on the competent authorities such as checking safety cases and certification activities.

It is anticipated that the sequencing of local deployments to be coordinated by the member states will ensure a smooth implementation avoiding peak of activities for ATSPs/aerodrome operators and their corresponding competent authorities.

It is also anticipated that the deployment plans will ensure a smooth publication of the new approach in the National AIPs by the Member States and, therefore, a subsequent smooth and swift processing of these AIPs by the Data Aggregators and Data Integrators.

##### *4.5.5.2.3 Conclusion on the costs and benefits of the implementation of RNP approaches*

By Option 0, the implementation of RNP APCH approach procedures will continue to occur on a voluntary basis. This option bears also the risk of a non-harmonised PBN implementation, hence, of extra costs.

By Option 1, the same performance objectives will be met but additional cost will be incurred at the runway ends where there would be no immediate requirement to improve the assessability performance (i.e. EUR 30 000 to EUR 47 500 per runway end).

In addition, by Option 1, on top of the APV approach procedure, the continuous availability of non-PBN facilities to accommodate the non-PBN-equipped traffic may represent additional costs for ATSPs/aerodrome operators although it can be assumed that in most cases, the current existing procedure may be used in that context. This specific obligation may imply additional cost for Option 1 compared to Option 0.

Taking into account the 10 runway ends studied (see footnote No 33) that match the criteria of Option 1 (5 runway ends in France and 5 runway ends in Finland), an average operational benefit of EUR 92 101 per runway end and per year can be derived which is approximately twice as high the unit cost of implementing an APV approach procedure. The costs of implementation should be supported by the local ATSPs/aerordrome operators, as they would benefit from a better and safer accessibility to the aerodrome even under adverse weather conditions, thus having a better predictability of the revenues associated with landing fees. These additional benefits are difficult to assess as there is significant variance dependent upon the local conditions and environment. The aircraft operators that access the aerodrome, provided that their aircraft and crew are qualified, will enjoy the benefits estimated above due to the reduced number of disruptions.

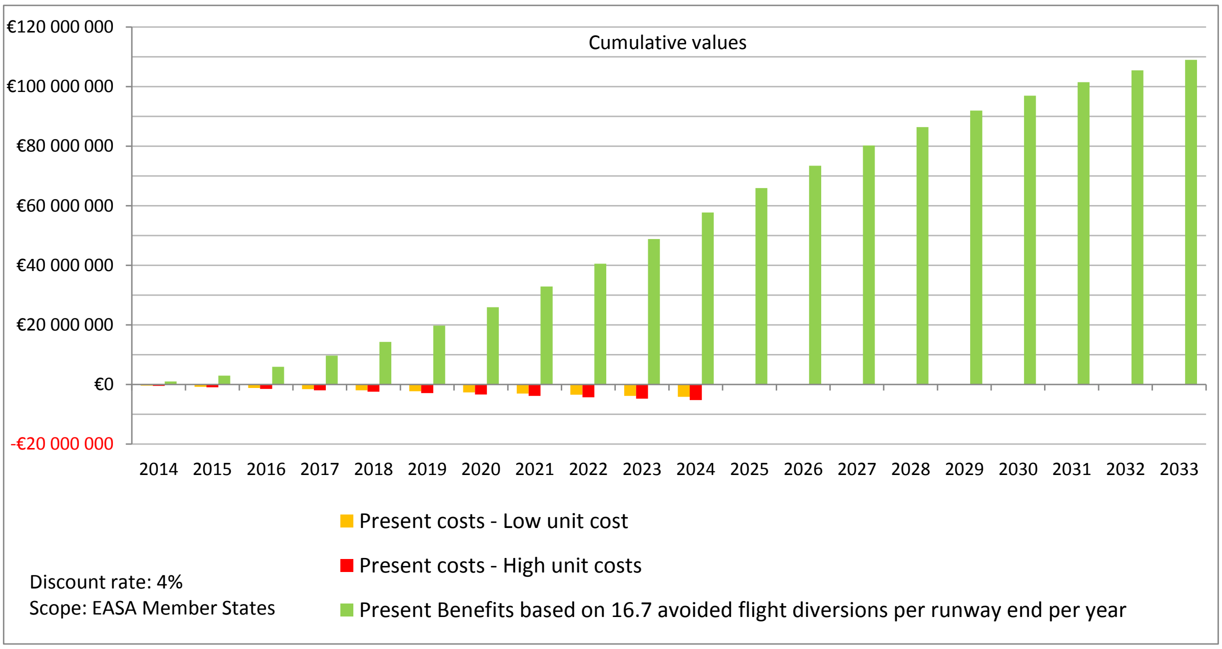
It should also be noted that, in the meantime, irrespective of the estimated operational benefits associated with the decrease of disruptions, APV approach procedures have nevertheless been already implemented, whilst the pre-existing non-precision approach procedures are still available.

**Table 9: Final approaches — Total costs (APV procedures) and benefits (avoided diversions) for EASA MS, 2014-2033**

| Range | Costs of APV approach procedures | Maximum benefits[35] (avoided diversion fligths) | Net Present Value |
|---|---|---|---|
| Scenario 1 — 399 IRE and 16.7 avoided diversions per IRE | | | |
| | Not discounted | | |
| Low | EUR –12 | EUR 3 773 | *N/A* |
| High | EUR –19 | | |
| | Discounted (4 %) | | |
| Low | EUR –9 | EUR 256 | EUR 247 |
| High | EUR –14 | | EUR 242 |

Note: For more details, see Appendix 3.

**Figure 8 — Cash flows for APV approach procedures comparing Option 1 against Option 0 (EASA Member States, 2014-2033, 4 % discount rate)**




### *4.5.5.3 Operations within SIDs and STARs*

#### *4.5.5.3.1 Benefits of implementing PBN in SIDs and STARs*

Implementing PBN SIDs and STARs allows for increasing capacity and environmental benefits by reducing route spacing whilst maintaining efficient and direct routes (RNP1 in straight lines and RF in turns)

[35] This is a maximum benefit in the sense that it assumes that the aircraft fleet would be fully equipped for APV approach. There is no reliable estimate of the current fleet equipped with APV approach.

The benefits that can be expected from the implementation of PBN in SIDs and STARs are already assessed in 4.5.2.2 together with the corresponding environmental benefits. The fuel savings which bring environmental benefits will also lead to cost savings (a price of EUR 0.70 per kg has been used).

**Table 10: PBN SIDs and STARs — Fuel savings**

| | ***Average fuel saving per flight (kg)*** | ***Average fuel saving per flight (EUR)*** |
|---|---|---|
| PBN SID | 0–30 | 0–20 |
| PBN STAR | 20–50 | 14–34 |

#### *4.5.5.3.2 Cost of implementing PBN in SIDs and STARs*

Whichever option is selected, the cost of implementing new PBN SIDs and STARs will be the same.

However,

— Option 0 bears the risk of a non-harmonised PBN implementation, which means extra costs;

— in the context of Option 1, ATSPs will have also to render available to airspace users procedures to provide access for non-PBN-equipped aircraft, with potential constraints and limitations.

#### *4.5.5.3.3 Conclusion on costs and benefits of the implementation of PBN in SIDs and STARs*

Whichever option is selected, the implementation of PBN SIDs and STARs will occur only where it is needed to meet performance objectives.

The potential operational benefits of both regulatory options will be the same.

Option 0 bears the risk of a non-harmonised PBN implementation, which means extra costs.

Option 1 requires the support of mixed operations (PBN and non-PBN) for incoming and outgoing traffic, which may have additional costs.

When the implementation of PBN SIDs and STARs will be defined as a cost-efficient means to achieve the performance objectives, the obligation to accommodate a certain level of mixed operations(PBN and non-PBN) will have been taken into account in the analysis of the different options. Therefore, when implementation of PBN SIDs and STARs occurs, it will always be cost and performance-efficient.

### *4.5.5.4 Operations along ATS Routes (en route or terminal operations)*

#### *4.5.5.4.1 Benefits of implementing ATS PBN routes*

Designing PBN based ATS routes, in accordance with the performance and functionalities described in Option 1, provides the opportunity to design shorter and more direct ATS routes, thus achieving fuel savings.

The aircraft performance and functionalities described in Option 1 bring improvements on the integrity of operations allowing for implementation of smaller route separation minima (along straight lines and during turns) therefore, combining the provision of higher capacity with maintaining ATS route length close to its optimum.

The implementation of FRT (above FL 195), in particular, will ensure better adherence to the ATS route centreline in curved segments allowing for a reduction of the route spacing around turns. On the other hand, the increase of traffic together with the reduction of the route spacing indicates a possible increase in the frequency on which wake turbulence is encountered. However, studies undertaken by EUROCONTROL have shown that, in the current European environment, a route spacing of 7 NM would be a reasonable objective and, by a wind-speed of 50 knots, the wake turbulence would take more than 6 minutes to propagate over 7 NM. After 6 minutes the residual wake turbulence is negligible and, therefore, the risk is considered to be acceptable under these assumptions.

From the safety point of view:

— the ATC working method will be impacted by the reduction of the route spacing;

— the on-board navigation database must ensure the correct coding of the required Lateral Navigation Accuracy to enable safe operations; and

— the correct publication of aeronautical information and identification of airways on aeronautical charts.

As already stated in 4.5.1.2, it is assumed that the implementation of the outcome of RMT.0477 (‘Technical requirements and operational procedures for aeronautical information services (AIS) and aeronautical information management (AIM)’) will ensure the required level of data integrity and accuracy needed allowing for a safe implementation of PBN routes.

#### *4.5.5.4.2 Cost of implementing ATS PBN routes*

Whichever option is selected, the cost of implementing new PBN ATS routes will be the same.

However:

— Option 0 bears the risk of a non-harmonised PBN implementation, which means extra costs;

— in the context of Option 1, the ATSPs in coordination with the Network manager will have to make available to airspace users ATS routes based on conventional navigation, with potential constraints and limitations. This specific obligation may entail additional costs compared to Option 0. Some existing non-PBN ATS routes may be reused for that purpose but it may also require designing and implementing new non-PBN ATS routes as well.

#### *4.5.5.4.3 Conclusion on costs and benefits of implementation of PBN ATS routes*

Whichever option is selected, the implementation of PBN-designed ATS routes will only occur where it is needed to meet performance objectives.

The potential efficiency and capacity benefits of both regulatory options are the same.

Option 0 bears the risk of a non-harmonised PBN implementation, which means extra costs.

Option 1 requires the continuous availability of alternative non-PBN ATS routes in addition to the cost-efficient PBN ATS routes; this may entail additional costs for the ATSPs and the Network Manager.

Nevertheless, when the implementation of PBN ATS routes will be defined as a cost-efficient means to achieve the performance objectives allocated to a portion of en-Route airspace, the continuous availability of these alternative non-PBN routes will have been taken into account in the analysis of the different options. Therefore, when implementation of PBN routes will take place, it will always be cost and performance-efficient.

#### 4.5.5.5 Overall economic impact

**Table 11: Global economic impact**

| *Areas of applicability* | *Option 0* | *Option 1* |
|---|---|---|
| Final Approach | – to 0 | + |
| SID/STAR | – to + | 0 to + |
| ATS Route | – to + | 0 to + |

### 4.5.6. Proportionality issues

#### 4.5.6.1 Proportionality analysis from an ATSP's/aerodrome operator's perspective

The estimated cost for the implementation of an APV approach procedure (minimum EUR 30 000 per runway end), is deemed reasonable when compared to the potential benefits (safety of operations, environmental and operational accessibility and efficiency) that it can bring to the stakeholders operating or accessing this type of instrument runway ends. However, for aerodromes with very low traffic, the implementation of an APV approach procedure may represent a significant investment.

When the costs of designing approach procedures are borne by the 'national' ATSP, they may represent a significant amount at national level; however, it is anticipated that they can be allocated over a multi-year programme for the implementation of PBN approach procedures.

#### 4.5.6.2 Proportionality analysis from an airspace user perspective

Under Option 1, the proposed regulation still foresees (cf. AUR.PBN.3005) the availability of non-PBN routes and procedures, although with possible constraints/limitations. This provision will allow aircraft operators (e.g. general aviation, state aircraft, business aviation), for which the cost of equipage and certification would be disproportionate with regard to the expected benefits for their operation, that they may obtain by using these PBN routes or procedures, to still access the airspace in accordance with the associated constraints/limitations if they are globally less expensive and less restrictive than retrofitting and recertifying the aircraft.

Under Option 0, it may occur that, when an ATSP/aerodrome operator implements PBN, this change will be followed by a discontinuation of non-PBN routes within their airspace of responsibility, thus rendering these procedures and routes and hence the airspace inaccessible to non-qualified aircraft.

During the preparation phase of redesigning the ATS routes, SIDs/STARs and/or the final approach procedures, it is anticipated that the communities of these stakeholders (general aviation, state aircraft, business aviation, etc.) will have the opportunity to negotiate with the relevant ATSPs/aerodrome operators and the Network Manager the non-PBN routes and procedures and their associated limitations/constraints so that they are actually useful for their respective specific types of operations. It should be recognised that formal consultation mechanisms are in place between Network Manager and military authorities (through the NMB) to take into account specific military needs and constraints.

#### *4.5.6.3 Proportionality impact assessment*

**Table 12: Proportionality impact**

| | Option 0 | Option 1 |
|---|---|---|
| Proportionality impact | 0 | 0 to + |

### *4.5.7. Impact on 'Better regulation' and harmonisation*

Whilst implementing PBN in the EATMN in the context of Option 0 will provide a wide range of benefits as described above, it may also induce airspace disharmonisation and airspace connectivity issues due to the potential implementation of various PBN specifications in different areas. These potential issues are further described in 4.5.5.1.

Under Option 1, by limiting the options for PBN ATS routes and procedures (AUR.PBN.2005), the proposed regulation tends to harmonise the use of final approach procedures and, for other types of operations, the deployment of PBN routes and procedures in the EATMN airspace with a single PBN specification for each type of operation.

Option 1 also provides a clear indication to the airspace users, aircraft manufacturers and avionics manufacturers of the qualification requirements for the performance and functionality of the aircraft area navigation systems for operations anywhere in Europe without any limitations or constraints.

For operations along ATS routes within SIDs and STARs, the implementation of airspace redesign is conditioned by the fact that this redesign is needed to meet the relevant performance objectives (AUR.PBN.2005.3-4). Therefore the proposed regulation does not mandate requirements containing a single implementation date of PBN, but provides flexibility, geographically and in terms of time, depending on the local environment, in order to implement airspace changes only where and when needed to reach performance objectives.

Because the future airspace re-design based on PBN will be announced sufficiently in advance (AUR.PBN.3010), airspace users and commercial air traffic operators, in particular, will be able to assess the costs/benefits of equipping or not their aircraft, of reallocating non-equipped aircraft (e.g. too expensive to retrofit or not yet retrofitted) to areas where PBN routes and procedures are not yet implemented or of accepting to fly the non-PBN routes or implement the non-PBN procedures with the associated possible limitations/constraints. Option 1 has been designed in accordance with a performance-based regulation approach where performance of the service provided is linked to the level of performance of the aircraft to which the service is provided. In that case, the highly performant aircraft (e.g. RNP1 with RF and FRT functional capabilities) will be able to fly the performant PBN ATS routes and implement the PBN ATS procedures, whereas less performant aircraft will have to fly conventional ATS routes and implement conventional ATS procedures which are less efficient and constrained by the positioning of the supporting ground Navaids.

#### *4.5.7.1 'Better regulation' and harmonisation impact assessment*

**Table 13: 'Better regulation' and harmonisation impact**

| | Option 0 | Option 1 |
|---|---|---|
| 'Better regulation' and harmonisation impact | – to 0 | + |

## 4.6. Comparison and conclusion

### *4.6.1. Comparison of options*

Tables 4, 7, 11, 12 and 13 provide the comparative assessment of Option 0 and Option 1 with respect to the 5 relevant criteria developed in paragraph 4.5 above (safety, environmental, economic = efficiency and costs, proportionality, and 'Better regulation' and harmonisation).

**Table 14: Overall assessment of Options 0 and 1 per type of operation and type of impacts**

| *Type of impacts* | *Final approach procedures* | | *SIDs and STARs procedures* | | *ATS routes* | |
|---|---|---|---|---|---|---|
| | *Option 0* | *Option 1* | *Option 0* | *Option 1* | *Option 0* | *Option 1* |
| Safety | 0 to + | + | 0 to + | + | N/A | N/A |
| Environmental | 0 to + | + | 0 to + | 0 to + | 0 to + | 0 to + |
| Economic | – to 0 | + | – to + | 0 to + | – to + | 0 to + |
| Proportionality | 0 | 0 to + | 0 | 0 to + | 0 | 0 to + |
| Better regulation & Harmonisation | – to 0 | + | – to 0 | + | – to 0 | + |
| **Overall** | **-** | **+** | **0** | **+** | **0** | **0 to +** |

In all, for each type of operations, Option 1 is the preferred one.

### *4.6.2. Sensitivity analysis*

Scenario 1 — Most probable scenario case: Option 1 is implemented on 399 runway ends.

The number of avoided flight diversions in the RNAV Approach Benefits Analysis — Final Report (20 May 2009) is estimated to 16.7 per runway end (Chapter 4.5.4.2.1). A sensitivity analysis was performed to check the reliability of the overall economic impacts. The approach was to assess the break-even point in terms of the number of avoided flight diversions which would offset the APV approach procedure's costs.

The maximum range of one-off costs to develop these procedures per runway end is from EUR 30 000 to EUR 47 500 (Chapter 4.5.4.2.2). The range of benefits per avoiding flight diversion is from EUR 820 to EUR 8 800 with an updated average of EUR 5 515 used for the RNAV Approach Benefits Analysis — Final Report (20 May 2009) (Chapter 4.5.4.2.1).

Based on these ranges of costs and benefits, the following table compares the number of avoided flight diversions to compensate the costs, providing the break-even point. This break-even point is further divided by 10 to assess the outcome in case the benefits would be 10 times lower than expected.

**Table 15: Number of avoided flight diversions to compensate the costs**

| *Range of one-off unit cost for an APV approach procedure at runway end* | *Range of benefits based on avoided flight diversion costs* | *Break-even point in terms of the number of avoided flight diversions to compensate the one-off costs* | *Break-even point factored by 10 (benefits are 10 times lower than expected)* |
|---|---|---|---|
| EUR 30 000 | EUR 820 | 37 | 3.7 |
| EUR 30 000 | EUR 8 800 | 3.4 | 0.3 |
| EUR 47 500 | EUR 820 | 58 | 5.8 |
| EUR 47 500 | EUR 8 800 | 5.4 | 0.5 |

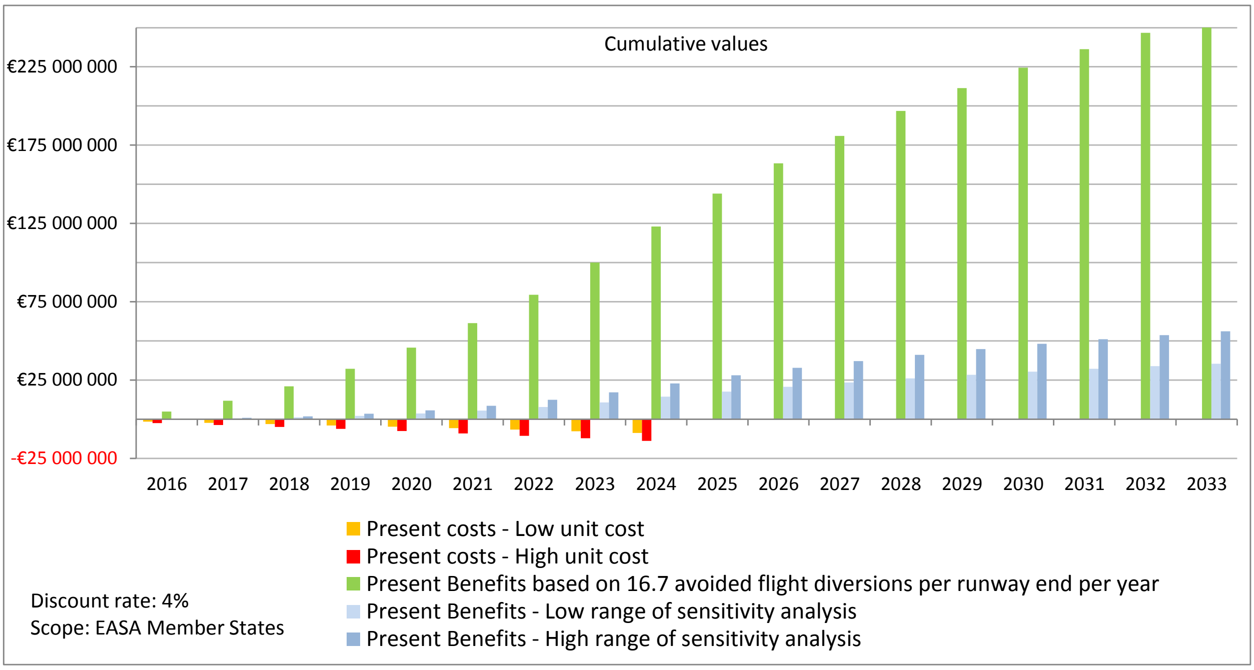
The break-even points are from 3.4 to 58 avoided flight diversions to compensate the one-off costs. This proves that the 16.7 avoided flight diversion is somehow in the average of the range of break-even points. If the benefits would be 10 times lower than expected, the break-even points would be from 0.3 to 5.8 avoided flight diversion, far less than the 16.7.

**Table 16: Sensitivity analysis — Global outcomes (EASA MS, 2016-2033, discount rate 4 %, millions in Euro, 2013)**

| *Assumption* | *Total cost of PBN approach procedures* | *Total benefits (avoided flight diversions)* | *Net Present Value* |
|---|---|---|---|
| 16.7 avoided flight diversion per runway end (Chapter 4.5.4.2.1) | EUR –9 000 000 to EUR –14 000 000 | EUR 256 000 000 | EUR 242 000 000 to EUR 247 000 000 |
| **Sensitivity analysis** | | | |
| 0.3 avoided flight diversion (Low unit cost & low benefit) | EUR –9 000 000 | EUR 36 000 000 | EUR 27 000 000 |
| 5.8 avoided flight diversion (High unit cost & high benefit) | EUR –14 000 000 | EUR 56 000 000 | EUR 42 000 000 |

The outcome of the sensitivity analysis is still positive over a period of 20 years. The net cash flow becomes positive after 7 years.

**Figure 9 — Sensitivity analysis of cash flows for APV approach procedures (EASA Member States, 2016-2033, 4 % discount rate)**




<u>Scenario 2</u> — <u>Extreme scenario case: Option 1 is implemented on 686 runway ends (in case that none of the current implementation plans would be fulfilled)</u>

The analysis follows the same principles as above and provides the same globlal outcome. For more details, see Appendix 3.

### _4.6.3. Monitoring and ex post evaluation_

It is expected that the monitoring of implementation will be performed as an SES implementation reporting of the MS and via EASA inspection programmes.

Taking into account the forthcoming action plan which is about to be launched by the ICAO EUR PBN Task Force in conjuction with the EUROCONTROL Navigation Subgroup following the results of the survey[36] undertaken in 2014 (cf. ICAO State Letter Reference EUR/NAT 14-0319.TEC), the Agency will initiate the monitoring of the availability of appropriately qualified staff and take the appropriate actions as required.

[36] ICAO EUR PBN TF/9 & EUROCONTROL NSG/20 — Agenda Item 3: Review of Action Lists ICAO EUR PBNTF EUROCONTROL NSG

# 5. References

## 5.1. Affected regulations

— Commission Regulation (EU) No 1332/2011 of 16 December 2011 laying down common airspace usage requirements and operating procedures for airborne collision avoidance (OJ L 336, 20.12.2011, p. 20);

— Commission Regulation (EU) No 965/2012 of 5 October 2012 laying down technical requirements and administrative procedures related to air operations pursuant to Regulation (EC) No 216/2008 of the European Parliament and of the Council (OJ L 296, 25.10.2012, p. 1).

## 5.2. Affected AMC and GM

Decision 2012/002/R of the Executive Director of the Agency of 8 March 2012 on the Acceptable Means of Compliance and Guidance Material for Common Airspace Usage Requirements and Operating Procedures 'AMC/GM to AUR'.

## 5.3. Reference documents

(a) Regulation (EC) No 552/2004 of the European Parliament and of the Council of 10 March 2004 on the interoperability of the European Air Traffic Management network (the interoperability Regulation) (OJ L 96, 31.3.2004, p. 26).

(b) Commission Implementing Regulation (EU) No 390/2013 of 3 May 2013 laying down a performance scheme for air navigation services and network functions (OJ L 128, 9.3.2013, p. 1).

(c) Commission Implementing Regulation (EU) No 716/2014 of 27 June 2014 on the establishment of the Pilot Common Project supporting the implementation of the European Air Traffic Management Master Plan (OJ L 190, 28.6.2014, p.19).

(d) Mandate to EUROCONTROL to assist the European Commission in the development of an interoperability implementing rule on Performance-Based Navigation (PBN), letter MOVE E2/EMM D(2011), 6 April 2011.

(e) Single European Sky (SES) Regulations. Regulatory approach for the draft Interoperability Implementing Rule on Performance-Based Navigation, March 2013, Edition 1.0.

(f) ICAO Assembly Resolution A37-11 — Performance-based navigation global goals, November 2010.

(g) ICAO Doc 9613 — Performance-Based Navigation (PBN) Manual, Fourth Edition, 2012.

(h) ICAO Doc 9750 — Global Air Navigation Plan 2013-2028.

(i) European Airspace Concept Handbook for PBN Implementation.

# 6. Appendices

**Appendix 1 — List of aerodromes relevant for the calculation of benefits of implementing an APV approach**

In relation with Chapter 4.5.4.2.1, the list of aerodromes relevant for the calculation of benefits of implementing an APV approach (RNAV Approach Benefits Analysis — Final Report (20 May 2009)) are:

— Clermont-Ferrand (LFLC);

— Bellegarde (LFBL): not in the scope of Commission Regulation (EU) No 139/2014 laying down requirements and administrative procedures related to aerodromes pursuant to Regulation (EC) No 216/2008 of the European Parliament and of the Council;

— Biarritz (LFBZ);

— Lille (LFQQ);

— Guipavas (LFRB : not in the scope of Commission Regulation (EU) No 139/2014 laying down requirements and administrative procedures related to aerodromes pursuant to Regulation (EC) No 216/2008 of the European Parliament and of the Council;

— Kittila (EFKT);

— Tampere-Pirkkala (EFTP);

— Rovaniemi (EFRO);

— Oulu (EFOU); and

— Ivalo (EFIV).

## Appendix 2 — Cost/benefit analysis table for Scenario 1 (implementation on 399 instrument runway ends)

*Note: IRE: Instrument Runway End*

### Table 1 — Development of APV approach on IRE and associated costs

| Year | Option 0 - Total IRE | | ICAO objective - Total IRE | Option 1 - Total IRE | | | Cumulative costs | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Annul trend to match the total 892 IRE in 2024 | 4.98% | Cumulative IRE | | | Cumulative IRE - base case because the rate of future implementation plans is in line with the observed rate of implemented 3D RNP approach | Cumulative IRE - Extreme case if the implementation plans are not respected | Scenario 1 | | Scenario 2 | |
| Annul trend to match the total 1291 IRE in 2033 | 4.20% | | 19.52% | 8.79% | *This is scenario 1 because it is the most probable scenario* | *This is scenario 2* | Low unit cost | High unit cost | Low unit cost | High unit cost |
| | | | | | | | | | | |
| Total 2016-2033 | | | | | | | **-€11 961 222** | **-€18 938 601** | **-€20 586 203** | **-€32 594 822** |
| 2015 | 605 | 0 | 1080 | 605 | | | €0 | €0 | €0 | €0 |
| 2016 | 605 | 0 | 1291 | 658 | 53 | 53 | -€1 595 385 | -€2 526 026 | -€1 590 000 | -€2 517 500 |
| 2017 | 635 | 30 | | 716 | 81 | 111 | -€2 421 749 | -€3 834 436 | -€3 325 619 | -€5 265 564 |
| 2018 | 667 | 62 | | 779 | 112 | 174 | -€3 361 047 | -€5 321 658 | -€5 213 800 | -€8 255 183 |
| 2019 | 700 | 95 | | 847 | 147 | 242 | -€4 419 061 | -€6 996 847 | -€7 267 951 | -€11 507 589 |
| 2020 | 735 | 130 | | 922 | 187 | 317 | -€5 608 028 | -€8 879 377 | -€9 502 662 | -€15 045 882 |
| 2021 | 771 | 166 | | 1003 | 231 | 398 | -€6 941 347 | -€10 990 466 | -€11 933 805 | -€18 895 191 |
| 2022 | 810 | 205 | | 1091 | 281 | 486 | -€8 433 693 | -€13 353 347 | -€14 578 644 | -€23 082 853 |
| 2023 | 850 | 245 | | 1187 | 337 | 582 | -€10 101 125 | -€15 993 448 | -€17 455 965 | -€27 638 612 |
| 2024 | 892 | 287 | | 1291 | 399 | 686 | **-€11 961 222** | **-€18 938 601** | **-€20 586 203** | **-€32 594 822** |
| 2025 | 930 | 325 | | | | | | | | |
| 2026 | 969 | 364 | | | | | | | | |
| 2027 | 1010 | 405 | | | | | | | | |
| 2028 | 1052 | 447 | | | | | | | | |
| 2029 | 1096 | 491 | | | | | | | | |
| 2030 | 1142 | 537 | | | | | | | | |
| 2031 | 1190 | 585 | | | | | | | | |
| 2032 | 1240 | 635 | | | | | | | | |
| 2033 | 1292 | 687 | | | | | | | | |

## Appendix 3 — Cost/benefit analysis table for Scenario 1 (implementation on 399 instrument runway ends)

*The study ‘RNAV Approach Benefits Analysis — Final Report (20 May 2009)’ is referred to as ‘Helios study’ in the following table to shorten the description.*

Table 2 — Benefits with Scenario 1 (scope = 399 IRE)

| Year | **Scenario 1 - Only runway ends without 3D PBN approach implementation plan are considered** | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Avoided diverted flights based on HELIOS study | | | | | Sensitivity analysis: | | | | | | | | | |
| | Annual number of avoided diverted flights based on HELIOS study | Cumulative number of avoided diverted flights based on HELIOS study | Cumulative benefits | | | Cumulative number of avoided diverted flights compensating the costs | | | | Total annual benefits | | | | Total cumulative benefits | |
| | | | Average | Low | High | x = | 10 years | | | Low unit cost | | High unit cost | | Low unit benefit | High unit benefit |
| | | | | | | Low unit benefit | High unit benefit | Low unit benefit | High unit benefit | Low unit benefit | High unit benefit | Low unit benefit | High unit benefit | | |
| Total | | | **€ 3 772 691 677** | **€ 560 944 184** | **€ 6 019 888 805** | | | | | **€ 69 062 814** | **€ 69 062 814** | **€ 109 349 456** | **€ 109 349 456** | **€ 69 062 814** | **€ 109 349 456** |
| 2015 | 0 | 0 | € - | € - | € - | 0 | 0 | 0 | 0 | € - | € - | € - | € - | € - | € - |
| 2016 | 888 | 888 | € 4 897 859 | € 728 240 | € 7 815 259 | 195 | 18 | 308 | 29 | € 159 539 | € 159 539 | € 252 603 | € 252 603 | € 159 539 | € 252 603 |
| 2017 | 1348 | 2236 | € 12 332 669 | € 1 833 688 | € 19 678 602 | 490 | 46 | 776 | 72 | € 401 713 | € 401 713 | € 636 046 | € 636 046 | € 561 252 | € 888 649 |
| 2018 | 1871 | 4107 | € 22 651 139 | € 3 367 894 | € 36 143 250 | 900 | 84 | 1425 | 133 | € 737 818 | € 737 818 | € 1 168 212 | € 1 168 212 | € 1 299 070 | € 2 056 861 |
| 2019 | 2460 | 6567 | € 36 217 731 | € 5 385 048 | € 57 790 758 | 1439 | 134 | 2278 | 212 | € 1 179 724 | € 1 179 724 | € 1 867 897 | € 1 867 897 | € 2 478 794 | € 3 924 758 |
| 2020 | 3122 | 9689 | € 53 434 469 | € 7 944 926 | € 85 262 616 | 2123 | 198 | 3361 | 313 | € 1 740 527 | € 1 740 527 | € 2 755 834 | € 2 755 834 | € 4 219 321 | € 6 680 592 |
| 2021 | 3864 | 13553 | € 74 744 521 | € 11 113 419 | € 119 265 962 | 2969 | 277 | 4701 | 438 | € 2 434 662 | € 2 434 662 | € 3 854 881 | € 3 854 881 | € 6 653 983 | € 10 535 473 |
| 2022 | 4695 | 18248 | € 100 636 098 | € 14 963 119 | € 160 579 811 | 3998 | 373 | 6330 | 590 | € 3 278 031 | € 3 278 031 | € 5 190 216 | € 5 190 216 | € 9 932 014 | € 15 725 689 |
| 2023 | 5623 | 23871 | € 131 646 720 | € 19 573 946 | € 210 061 856 | 5229 | 487 | 8280 | 772 | € 4 288 144 | € 4 288 144 | € 6 789 561 | € 6 789 561 | € 14 220 158 | € 22 515 249 |
| 2024 | 6658 | 30529 | € 168 367 871 | € 25 033 845 | € 268 655 895 | 6688 | 623 | 10590 | 987 | € 5 484 266 | € 5 484 266 | € 8 683 421 | € 8 683 421 | € 19 704 423 | € 31 198 670 |
| 2025 | 6658 | 37187 | € 205 089 021 | € 30 493 744 | € 327 249 934 | 6688 | 623 | 10590 | 987 | € 5 484 266 | € 5 484 266 | € 8 683 421 | € 8 683 421 | € 25 188 689 | € 39 882 091 |
| 2026 | 6658 | 43846 | € 241 810 171 | € 35 953 643 | € 385 843 972 | 6688 | 623 | 10590 | 987 | € 5 484 266 | € 5 484 266 | € 8 683 421 | € 8 683 421 | € 30 672 955 | € 48 565 511 |
| 2027 | 6658 | 50504 | € 278 531 322 | € 41 413 542 | € 444 438 011 | 6688 | 623 | 10590 | 987 | € 5 484 266 | € 5 484 266 | € 8 683 421 | € 8 683 421 | € 36 157 220 | € 57 248 932 |
| 2028 | 6658 | 57163 | € 315 252 472 | € 46 873 441 | € 503 032 050 | 6688 | 623 | 10590 | 987 | € 5 484 266 | € 5 484 266 | € 8 683 421 | € 8 683 421 | € 41 641 486 | € 65 932 353 |
| 2029 | 6658 | 63821 | € 351 973 622 | € 52 333 340 | € 561 626 088 | 6688 | 623 | 10590 | 987 | € 5 484 266 | € 5 484 266 | € 8 683 421 | € 8 683 421 | € 47 125 752 | € 74 615 773 |
| 2030 | 6658 | 70480 | € 388 694 773 | € 57 793 239 | € 620 220 127 | 6688 | 623 | 10590 | 987 | € 5 484 266 | € 5 484 266 | € 8 683 421 | € 8 683 421 | € 52 610 017 | € 83 299 194 |
| 2031 | 6658 | 77138 | € 425 415 923 | € 63 253 138 | € 678 814 166 | 6688 | 623 | 10590 | 987 | € 5 484 266 | € 5 484 266 | € 8 683 421 | € 8 683 421 | € 58 094 283 | € 91 982 615 |
| 2032 | 6658 | 83796 | € 462 137 073 | € 68 713 037 | € 737 408 204 | 6688 | 623 | 10590 | 987 | € 5 484 266 | € 5 484 266 | € 8 683 421 | € 8 683 421 | € 63 578 549 | € 100 666 035 |
| 2033 | 6658 | 90455 | € 498 858 224 | € 74 172 936 | € 796 002 243 | 6688 | 623 | 10590 | 987 | € 5 484 266 | € 5 484 266 | € 8 683 421 | € 8 683 421 | € 69 062 814 | € 109 349 456 |

Table 3 — Net present value for Scenario 1

| **Year** | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Discount rate | PV Cumulative Costs | | PV Cumulative Benefits | | | | | Net Present Value | | | |
| | | | | Benefits derived from Helios study | | | Sensitivity analysis: | annual diversions to compensate cost are spread over (divided by) 10 years. | based on average benefits | | Sensitivity analysis | |
| | 4% | Low unit cost | High unit cost | Average benefits | Low unit benefit | High unit benefit | Low unit benefit | High unit benefit | Low unit cost | High unit cost | Low unit benefit | High unit benefit |
| Total | | **-€8 739 948** | **-€13 838 250** | **€ 256 100 466** | **€ 74 172 936** | **€ 796 002 243** | **€ 35 455 001** | **€ 56 137 085** | **€247 360 518** | **€242 262 215** | **€26 715 054** | **€42 298 835** |
| 2015 | 1.00 | €0 | €0 | € - | € - | € - | € - | € - | | | €0 | €0 |
| 2016 | 1.00 | -€1 595 385 | -€2 526 026 | € 4 897 859 | € 728 240 | € 7 815 259 | € 159 539 | € 252 603 | | | -€1 435 847 | -€2 273 424 |
| 2017 | 0.96 | -€2 328 605 | -€3 686 958 | € 11 858 336 | € 1 833 688 | € 19 678 602 | € 539 665 | € 854 470 | | | -€1 788 940 | -€2 832 488 |
| 2018 | 0.92 | -€3 107 477 | -€4 920 172 | € 20 942 252 | € 3 367 894 | € 36 143 250 | € 1 201 063 | € 1 901 684 | | | -€1 906 413 | -€3 018 488 |
| 2019 | 0.89 | -€3 928 529 | -€6 220 171 | € 32 197 431 | € 5 385 048 | € 57 790 758 | € 2 203 639 | € 3 489 095 | | | -€1 724 890 | -€2 731 076 |
| 2020 | 0.85 | -€4 793 766 | -€7 590 129 | € 45 676 008 | € 7 944 926 | € 85 262 616 | € 3 606 694 | € 5 710 598 | | | -€1 187 072 | -€1 879 531 |
| 2021 | 0.82 | -€5 705 281 | -€9 033 362 | € 61 434 548 | € 11 113 419 | € 119 265 962 | € 5 469 089 | € 8 659 391 | | | -€236 192 | -€373 971 |
| 2022 | 0.79 | -€6 665 270 | -€10 553 344 | € 79 534 170 | € 14 963 119 | € 160 579 811 | € 7 849 415 | € 12 428 240 | | | €1 184 145 | €1 874 897 |
| 2023 | 0.76 | -€7 676 025 | -€12 153 706 | € 100 040 688 | € 19 573 946 | € 210 061 856 | € 10 806 151 | € 17 109 739 | | | €3 130 126 | €4 956 033 |
| 2024 | 0.73 | **-€8 739 948** | **-€13 838 250** | € 123 024 754 | € 25 033 845 | € 268 655 895 | € 14 397 829 | € 22 796 563 | | | €5 657 881 | €8 958 312 |
| 2025 | 0.70 | € - | € - | € 144 092 826 | € 30 493 744 | € 327 249 934 | € 17 697 239 | € 28 020 628 | | | €17 697 239 | €28 020 628 |
| 2026 | 0.68 | € - | € - | € 163 358 287 | € 35 953 643 | € 385 843 972 | € 20 721 549 | € 32 809 119 | | | €20 721 549 | €32 809 119 |
| 2027 | 0.65 | € - | € - | € 180 928 635 | € 41 413 542 | € 444 438 011 | € 23 487 041 | € 37 187 815 | | | €23 487 041 | €37 187 815 |
| 2028 | 0.62 | € - | € - | € 196 905 764 | € 46 873 441 | € 503 032 050 | € 26 009 149 | € 41 181 153 | | | €26 009 149 | €41 181 153 |
| 2029 | 0.60 | € - | € - | € 211 386 237 | € 52 333 340 | € 561 626 088 | € 28 302 505 | € 44 812 300 | | | €28 302 505 | €44 812 300 |
| 2030 | 0.58 | € - | € - | € 224 461 546 | € 57 793 239 | € 620 220 127 | € 30 380 974 | € 48 103 209 | | | €30 380 974 | €48 103 209 |
| 2031 | 0.56 | € - | € - | € 236 218 361 | € 63 253 138 | € 678 814 166 | € 32 257 693 | € 51 074 681 | | | €32 257 693 | €51 074 681 |
| 2032 | 0.53 | € - | € - | € 246 738 762 | € 68 713 037 | € 737 408 204 | € 33 945 107 | € 53 746 419 | | | €33 945 107 | €53 746 419 |
| 2033 | 0.51 | € - | € - | € 256 100 466 | € 74 172 936 | € 796 002 243 | € 35 455 001 | € 56 137 085 | | | €35 455 001 | €56 137 085 |

## Appendix 4 — Cost/benefit analysis table for Scenario 2 (implementation on 686 instrument runway ends)

Table 1 — Benefits with Scenario 2

| Year | Scenario 2 (extreme scenario): scope = all runways in 2013 without 3D PBN approach procedures | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Avoided diverted flights based on HELIOS study | | | | | Sensitivity analysis: | | | | | | | | | |
| | Annual number of avoided diverted flights based on HELIOS study | Cumulative number of avoided diverted flights based on HELIOS study | Cumulative benefits | | | Cumulative number of avoided diverted flights compensating the costs | | | | Total annual benefits | | | | Total cumulative benefits | |
| | | | Average | Low | High | x = | 10 | years | | Low unit cost | | High unit cost | | Low unit benefit | High unit benefit |
| | | | | | | Low unit benefit | High unit benefit | Low unit benefit | High unit benefit | Low unit benefit | High unit benefit | Low unit benefit | High unit benefit | | |
| Total 2016-2033 | | | **€ 6 339 501 042** | **€ 942 591 270** | **€ 10 115 613 630** | | | | | **€ 113 859 370** | **€ 113 859 370** | **€ 180 277 336** | **€ 180 277 336** | **€ 113 859 370** | **€ 180 277 336** |
| 2015 | 0 | 0 | € - | € - | € - | 0 | 0 | 0 | 0 | € - | € - | € - | € - | € - | € - |
| 2016 | 885 | 885 | € 4 881 327 | € 725 782 | € 7 788 880 | 194 | 18 | 307 | 29 | € 159 000 | € 159 000 | € 251 750 | € 251 750 | € 159 000 | € 251 750 |
| 2017 | 1851 | 2736 | € 15 091 033 | € 2 243 816 | € 24 079 981 | 599 | 56 | 949 | 88 | € 491 562 | € 491 562 | € 778 306 | € 778 306 | € 650 562 | € 1 030 056 |
| 2018 | 2902 | 5639 | € 31 097 485 | € 4 623 742 | € 49 620 647 | 1235 | 115 | 1956 | 182 | € 1 012 942 | € 1 012 942 | € 1 603 825 | € 1 603 825 | € 1 663 504 | € 2 633 881 |
| 2019 | 4046 | 9685 | € 53 410 216 | € 7 941 319 | € 85 223 916 | 2122 | 198 | 3359 | 313 | € 1 739 737 | € 1 739 737 | € 2 754 584 | € 2 754 584 | € 3 403 241 | € 5 388 465 |
| 2020 | 5290 | 14974 | € 82 583 547 | € 12 278 968 | € 131 774 291 | 3280 | 306 | 5194 | 484 | € 2 690 003 | € 2 690 003 | € 4 259 172 | € 4 259 172 | € 6 093 244 | € 9 647 636 |
| 2021 | 6643 | 21618 | € 119 220 526 | € 17 726 352 | € 190 234 021 | 4736 | 441 | 7498 | 699 | € 3 883 384 | € 3 883 384 | € 6 148 691 | € 6 148 691 | € 9 976 628 | € 15 796 327 |
| 2022 | 8115 | 29733 | € 163 977 207 | € 24 381 017 | € 261 649 940 | 6514 | 607 | 10313 | 961 | € 5 341 248 | € 5 341 248 | € 8 456 976 | € 8 456 976 | € 15 317 876 | € 24 253 303 |
| 2023 | 9717 | 39450 | € 217 567 312 | € 32 349 083 | € 347 160 896 | 8642 | 805 | 13684 | 1275 | € 7 086 845 | € 7 086 845 | € 11 220 837 | € 11 220 837 | € 22 404 720 | € 35 474 141 |
| 2024 | 11460 | 50910 | € 280 767 298 | € 41 745 999 | € 448 005 843 | 11153 | 1039 | 17659 | 1645 | € 9 145 465 | € 9 145 465 | € 14 480 320 | € 14 480 320 | € 31 550 185 | € 49 954 460 |
| 2025 | 11460 | 62369 | € 343 967 285 | € 51 142 915 | € 548 850 791 | 11153 | 1039 | 17659 | 1645 | € 9 145 465 | € 9 145 465 | € 14 480 320 | € 14 480 320 | € 40 695 650 | € 64 434 780 |
| 2026 | 11460 | 73829 | € 407 167 272 | € 60 539 830 | € 649 695 738 | 11153 | 1039 | 17659 | 1645 | € 9 145 465 | € 9 145 465 | € 14 480 320 | € 14 480 320 | € 49 841 115 | € 78 915 099 |
| 2027 | 11460 | 85289 | € 470 367 259 | € 69 936 746 | € 750 540 685 | 11153 | 1039 | 17659 | 1645 | € 9 145 465 | € 9 145 465 | € 14 480 320 | € 14 480 320 | € 58 986 580 | € 93 395 419 |
| 2028 | 11460 | 96748 | € 533 567 246 | € 79 333 661 | € 851 385 632 | 11153 | 1039 | 17659 | 1645 | € 9 145 465 | € 9 145 465 | € 14 480 320 | € 14 480 320 | € 68 132 045 | € 107 875 738 |
| 2029 | 11460 | 108208 | € 596 767 233 | € 88 730 577 | € 952 230 580 | 11153 | 1039 | 17659 | 1645 | € 9 145 465 | € 9 145 465 | € 14 480 320 | € 14 480 320 | € 77 277 510 | € 122 356 058 |
| 2030 | 11460 | 119668 | € 659 967 219 | € 98 127 492 | € 1 053 075 527 | 11153 | 1039 | 17659 | 1645 | € 9 145 465 | € 9 145 465 | € 14 480 320 | € 14 480 320 | € 86 422 975 | € 136 836 377 |
| 2031 | 11460 | 131127 | € 723 167 206 | € 107 524 408 | € 1 153 920 474 | 11153 | 1039 | 17659 | 1645 | € 9 145 465 | € 9 145 465 | € 14 480 320 | € 14 480 320 | € 95 568 440 | € 151 316 697 |
| 2032 | 11460 | 142587 | € 786 367 193 | € 116 921 323 | € 1 254 765 421 | 11153 | 1039 | 17659 | 1645 | € 9 145 465 | € 9 145 465 | € 14 480 320 | € 14 480 320 | € 104 713 905 | € 165 797 016 |
| 2033 | 11460 | 154047 | € 849 567 180 | € 126 318 239 | € 1 355 610 369 | 11153 | 1039 | 17659 | 1645 | € 9 145 465 | € 9 145 465 | € 14 480 320 | € 14 480 320 | € 113 859 370 | € 180 277 336 |

Table 2 — Net present value for Scenario 2

| Year | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Discount rate | PV Cumulative Costs | | PV Cumulative Benefits | | | | | Net Present Value | | | |
| | | | | Benefits derived from Helios study | | | Sensitivity analysis: | annual diversions to compensate cost are spread over (divided by) 10 years. | based on average benefits | | Sensitivity analysis | |
| | 4% | Low unit cost | High unit cost | Average benefits | Low unit benefit | High unit benefit | Low unit benefit | High unit benefit | Low unit cost | High unit cost | Low unit benefit | High unit benefit |
| | | | | | | | | | | | | |
| Total 2016-2033 | | **-€15 042 137** | **-€23 816 717** | **€ 436 145 061** | **€ 64 848 404** | **€ 695 934 095** | **€ 58 452 354** | **€ 92 549 561** | **€421 102 924** | **€412 328 344** | **€43 410 217** | **€68 732 844** |
| 2015 | 1.00 | €0 | €0 | € - | € - | € - | € - | € - | | | €0 | €0 |
| 2016 | 1.00 | -€1 590 000 | -€2 517 500 | € 4 881 326.50 | € 725 782.00 | € 7 788 880.00 | € 159 000.00 | € 251 750.00 | | | -€1 431 000 | -€2 265 750 |
| 2017 | 0.96 | -€3 197 711 | -€5 063 042 | € 14 510 608.95 | € 2 157 515.75 | € 23 153 827.51 | € 625 540.32 | € 990 438.84 | | | -€2 572 171 | -€4 072 603 |
| 2018 | 0.92 | -€4 820 451 | -€7 632 380 | € 28 751 373.01 | € 4 274 909.50 | € 45 877 077.51 | € 1 538 002.80 | € 2 435 171.10 | | | -€3 282 448 | -€5 197 209 |
| 2019 | 0.89 | -€6 461 182 | -€10 230 205 | € 47 481 487.18 | € 7 059 804.08 | € 75 763 751.08 | € 3 025 468.70 | € 4 790 325.44 | | | -€3 435 713 | -€5 439 879 |
| 2020 | 0.85 | -€8 122 915 | -€12 861 283 | € 70 592 761.98 | € 10 496 113.29 | € 112 641 215.85 | € 5 208 530.54 | € 8 246 840.01 | | | -€2 914 385 | -€4 614 443 |
| 2021 | 0.82 | -€9 808 717 | -€15 530 469 | € 97 990 581.73 | € 14 569 769.18 | € 156 358 498.51 | € 8 200 060.74 | € 12 983 429.50 | | | -€1 608 657 | -€2 547 040 |
| 2022 | 0.79 | -€11 521 714 | -€18 242 714 | € 129 593 568.28 | € 19 268 671.98 | € 206 785 748.11 | € 12 105 939.74 | € 19 167 737.92 | | | €584 225 | €925 024 |
| 2023 | 0.76 | -€13 265 099 | -€21 003 074 | € 165 333 275.60 | € 24 582 644.78 | € 263 813 748.91 | € 17 025 746.15 | € 26 957 431.40 | | | €3 760 647 | €5 954 358 |
| 2024 | 0.73 | -€15 042 137 | -€23 816 717 | € 205 153 914.79 | € 30 503 392.59 | € 327 353 481.44 | € 23 053 411.42 | € 36 501 234.75 | | | €8 011 274 | €12 684 518 |
| 2025 | 0.70 | €0 | €0 | € 241 666 852.04 | € 35 932 333.40 | € 385 615 285.22 | € 28 592 224.12 | € 45 271 021.52 | | | €28 592 224 | €45 271 022 |
| 2026 | 0.68 | €0 | €0 | € 275 067 619.69 | € 40 898 540.01 | € 438 911 161.07 | € 33 670 871.62 | € 53 312 213.40 | | | €33 670 872 | €53 312 213 |
| 2027 | 0.65 | €0 | €0 | € 305 541 602.18 | € 45 429 576.39 | € 487 536 917.35 | € 38 316 557.74 | € 60 667 883.09 | | | €38 316 558 | €60 667 883 |
| 2028 | 0.62 | €0 | €0 | € 333 264 527.40 | € 49 551 570.71 | € 531 772 953.97 | € 42 555 074.41 | € 67 378 867.82 | | | €42 555 074 | €67 378 868 |
| 2029 | 0.60 | €0 | €0 | € 358 402 935.30 | € 53 289 285.03 | € 571 885 010.09 | € 46 410 870.04 | € 73 483 877.56 | | | €46 410 870 | €73 483 878 |
| 2030 | 0.58 | €0 | €0 | € 381 114 624.65 | € 56 666 181.72 | € 608 124 877.04 | € 49 907 114.71 | € 79 019 598.29 | | | €49 907 115 | €79 019 598 |
| 2031 | 0.56 | €0 | €0 | € 401 549 079.11 | € 59 704 486.83 | € 640 731 078.19 | € 53 065 762.35 | € 84 020 790.38 | | | €53 065 762 | €84 020 790 |
| 2032 | 0.53 | €0 | €0 | € 419 847 873.43 | € 62 425 250.45 | € 669 929 516.99 | € 55 907 610.00 | € 88 520 382.49 | | | €55 907 610 | €88 520 382 |
| 2033 | 0.51 | €0 | €0 | € 436 145 060.68 | € 64 848 404.31 | € 695 934 095.01 | € 58 452 354.33 | € 92 549 561.03 | | | €58 452 354 | €92 549 561 |