



WORKING PAPER

TWELFTH AIR NAVIGATION CONFERENCE

Agenda Item 2: Aerodrome operations – improving airport performance

2.2: Performance-based navigation (PBN) – a practical way to improve airport performance with safety and efficiency

PBN FOR TERMINAL AND APPROACH OPERATIONS

(Presented by the Secretariat)

EXECUTIVE SUMMARY

The introduction of the performance-based navigation (PBN) concept has been successful, but implementation is still lagging behind. Near-term plans bring many additional benefits but they are contingent upon adequate training, expert support to States, continued maintenance and further development of ICAO provisions for advanced applications of PBN, and close coordination between all the aviation stakeholders. The challenge is to ensure that all these areas continue to be addressed.

Action: The Conference is invited to approve the recommendation in paragraph 7.

<i>Strategic Objectives:</i>	This working paper relates to the Safety and Environmental Protection and Sustainable Development of Air transport Strategic Objectives.
<i>Financial implications:</i>	Most navigation specifications can be met with existing on-board equipment and therefore little or no investment is required. During any implementation a cost-benefit analysis needs to be undertaken to determine whether the proposed PBN implementation is cost-effective. Early standardization of future PBN requirements should allow a coordinated development by industry which should, in turn, lead to lower costs in future implementations.
<i>References:</i>	Doc 9958, <i>Assembly Resolutions in Force (as of 8 October 2010)</i> Doc 9613, <i>Performance-based Navigation (PBN) Manual</i>

1. BACKGROUND

1.1 The introduction of the performance-based navigation (PBN) concept provided a clear methodology for the implementation of area navigation (RNAV) based procedures and routes, supported by a globally-standardized set of navigation specifications for RNAV-based ATS routes, standard instrument departures (SIDs), standard terminal arrival routes (STARs), and approaches. This drew together and rationalized existing approval material that had already been published by some States. The existence of the *Performance-based Navigation (PBN) Manual* (Doc 9613) and PBN-related material in Standards and Recommended Practices (SARPs), Procedures for Air Navigation Services (PANS) and guidance documents allowed the accelerated implementation of vertically guided instrument approaches that had been identified as an action in ICAO Assembly Resolution A36/23 and, again, in ICAO Assembly Resolution A37/11. This

supports the implementation of stabilized approaches which have been called for to help reduce in the number of controlled flights into terrain. The PBN concept also facilitated the global development of RNAV SIDs and STARs to a common set of standards.

1.2 This paper is one of two PBN working papers submitted to the Conference. The additional working paper, AN-Conf/12-WP/16, addresses PBN in en-route operations and is submitted under Agenda 5.1

2. CURRENT STATUS

2.1 The current PBN concept is based upon the first edition of the PBN Manual which supports RNAV 2, RNAV 1 and RNP 1 applications in terminal airspace as well as required navigation performance (RNP) approaches and RNP authorization required (AR) approaches. Procedure design, procedure validation and charting criteria have been published by ICAO to ensure a standard global implementation.

3. APPROACHES

3.1 ICAO Assembly Resolution A37/11 calls for implementation of PBN approach procedures with vertical guidance (APV) with satellite-based augmentation system (SBAS) or barometric vertical navigation (Baro-VNAV)) or, where vertical guidance is not available, with lateral guidance only to most instrument flight rules (IFR) runway ends, by 2016.

3.2 As a consequence of this resolution, PBN approaches, many incorporating vertical guidance, are being published at a growing rate throughout the world (see Figure 1). More exacting, AR approaches have been developed in a number of locations where terrain limits access to the aerodrome. However, while some States will be able to meet Assembly Resolution A37/11 by 2016, the observed rate of implementation of PBN RNP approaches around the world shows that this target will not be met on a global basis. The reasons for this implementation delay are explained in paragraph 6 of the paper, and ICAO should continue to encourage States to implement RNP approaches and should provide support where necessary.

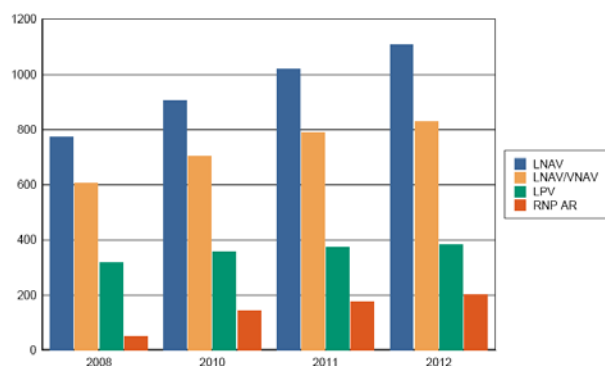


Figure 1. Global implementation of PBN approaches on international runways

4. TERMINAL PROCEDURES

4.1 Many major airports now have RNAV 1 or RNP 1 SIDS and STARs and, in a large number of cases, judicious design has resulted in significant savings in track miles and reductions in the environmental impact (see Figure 2). This is particularly the case where the airspace design has supported continuous descent and continuous climb operations. ICAO has recently published manuals on continuous descent operations (CDO) and continuous climb operations (CCO). Both these documents provide guidance in the design,

implementation and operation of environmentally friendly arrivals and departures. CDOs in combination with CCOs can ensure that the efficiency of the terminal operation is safely maximized with a significantly reduced environmental impact. In order for this to be fully implemented, ATM tools and techniques have to be updated to ensure that the arrival and departure flows are smooth and appropriately sequenced.

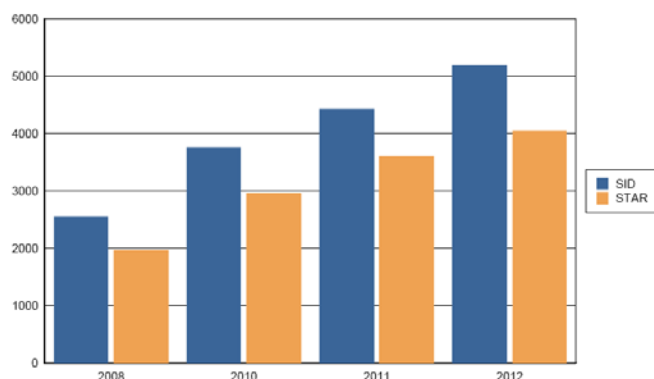


Figure 2. Global implementation of PBN SIDs and STARs

5. FUTURE PLANS

5.1 The PBN concept is being expanded to accommodate three new navigation applications, two of which affect terminal and approach operations:

- a) advanced RNP (ARNP) will provide a single aircraft qualification requirement for all terminal applications. This simplification should, in time, reduce costs to operators and improve understanding amongst pilots and controllers. ARNP requires RNP 1 in all terminal phases and RNP 0.3 in final approach. It also requires constant radius arc to a fix (RF) functionality in all aircraft, thereby improving track predictability and allowing closer route spacing. ARNP will introduce “scaleability” where flexible navigation accuracy requirements will bring better access in obstacle rich environments, allow more flexible designs to reduce noise footprints and provide better support for parallel approach and departure operations; and
- b) RNP 0.3 will enable helicopter operations with reduced impact on airspace use and improved access for both arrivals and departures.

5.2 It is anticipated that future PBN developments will include RNP AR departures as well as new ARNP options, including time of arrival control in terminal airspace, improved vertical navigation (VNAV) operations and improved navigation performance in holding.

6. OUTSTANDING ISSUES

6.1 The implementation of PBN applications involves a wide range of specializations from airspace and procedure designers to regulators, cartographers, flight dispatchers, air traffic controllers and pilots. The biggest challenge to date has been to ensure that there is a common global understanding of the PBN concept and the way in which it is implemented. Training and awareness activities must be made available on a global basis. This means that there is an ongoing need for guidance material, workshops, symposia, computer-based learning packages and formal courses to ensure that the requirements and Standards are fully understood and

properly implemented. This demand for training and awareness is not expected to reduce until some years after PBN is established as the standard method of navigation. The introduction of new navigation applications means that there is a continuing need for the Standards, guidance material and training packages to be updated and improved.

6.2 As PBN becomes the standard method of operation and takes over from conventional navigation so the crew/ATC procedures associated with PBN will become the standard operating procedures and the training requirements will be subsumed in the ab initio, type qualification and continuation training programmes. This will take time and the period of transition will continue to generate challenges that will have to be addressed. Notwithstanding the programme of workshops and Go-team visits that have already been carried out, there is still an urgent need for training and awareness activities.

6.3 A number of States lack the relevant PBN expertise in many of the specialist fields and a comprehensive support programme, managed by the ICAO regional offices, is an essential prerequisite to a successful PBN implementation.

6.4 The PBN operations approval process, despite the guidance that is already provided in Doc 9613, still seems to be not fully understood in many States and the recognition of foreign approvals in a State is not as widespread as expected. Additional guidance is incorporated in the latest version of Doc 9163, an ops approval manual, a short course for regulators is being developed by ICAO and this is supplemented by a computer based learning package. Closer coordination between States and a commitment to harmonization of approval procedures by the major aviation States will help to resolve this issue.

6.5 Standards development must continue to be actively supported for advanced applications of PBN. While many of the design criteria to support applications using the new navigation specifications are close to completion, there is still work to be done in the fields of RNP AR design, route spacing, PBN charting, ATC procedures, traffic separation, operational approval and aeronautical data publication. Moreover, as experience is gained in deploying the new capabilities, there will be a need to review and modify the existing criteria to ensure that the maximum benefit is being gained. Route spacing and separation criteria in particular will need further assessment as more track-keeping data becomes available, as the communications, navigation and surveillance/air traffic management (CNS/ATM) systems become more sophisticated and as the ATC concepts of operations take account of these technological changes. This should also lead to clarification of the use of PBN to support strategically separate SIDs and STARs as well as closely spaced parallel approach and departure operations.

6.6 Future implementations of PBN in terminal airspace will also rely on improved and more closely integrated communications (data linked aircraft position and intent; current wind and temperature; trajectory requests and ATC clearances), surveillance (ADS) and support tools (in the approach control service/area control centre (APP/ACC), on the flight deck and in flight operations). PBN will be one of the key enablers for the future terminal operations envisaged by a mature modernization programme. This means that there must be close, continuous coordination between the different project offices and the standards developers. Moreover, ATC and flight management tools must be developed to better realize the benefits from PBN. Research and development must be actively supported by the global community. The development of complex ATM systems, and the integration of the airborne systems with the ground systems, means that there will be ever greater reliance on automation, GNSS and data links. For this development to be successful the interfaces between the various systems must be standardized and the operational concepts must take full account of the strengths and weaknesses of the various components. PBN is a major component of the system and it is imperative that it and the associated applications are correctly integrated in the bigger plan. The ASBU concept provides a very high level management tool to start ensuring that the components are suitably matched. However, there must be very careful attention paid to the details and a long-term commitment to such development is necessary if there are to be dividends in the future.

7. CONCLUSION

7.1 The Conference is invited to agree to the following recommendation:

Recommendation 2/x – Performance-based navigation (PBN) for terminal- and approach- operations implementation

Considering that performance-based navigation (PBN) is ICAO's highest air navigation priority and the potential benefits achievable through creation of additional capacity with PBN, it is recommended that:

- a) States are urged as a matter of urgency to implement performance-based navigation for terminal- and approach-operations;
- b) States, considering the need for an effective implementation of performance-based navigation, adopt efficient operations approval procedures and support the mutual recognition of other States' approvals;
- c) All stakeholders, considering the benefits to be gained in terms of improved safety, reduced operating costs and reduced environmental impact, seek to work together in close coordination to ensure successful performance-based navigation implementations throughout the world;
- d) States, international organizations and industry coordinate at all levels to expedite performance-based navigation implementation; and
- e) ICAO in coordination with its partners continue to work on assisting States implementing performance-based navigation (PBN) and developing provisions for advance use of PBN.

Recommendation 2/x – Performance-based navigation (PBN) provisions, guidance and training material

That States, international organizations and industry continue to provide resources to support ICAO on the development of provisions, guidance and training material in support of performance-based navigation implementation.

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