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GNSS Navigation for Enabling More Efficient and Effective Air Traffic Management

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Abstract

Area navigation (RNAV) and other appropriate navigation specifications of the ICAO Performance Based Navigation concept represents a significant shift from conventional radio navigation to navigation primarily based on the Global Navigation Satellite System (GNSS), which is poised to become the primary, and potentially only, means of air navigation. Here we demonstrate that using RNAV to define routes in one airspace sector over Croatia can reduce the number of potential conflicts between aircraft and thereby increase flight efficiency. At the same time, this can reduce the costs associated with air traffic management, thereby increasing effectiveness.

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Keywords: Area navigation; air traffic; traffic congestions

1. Introduction

In conventional radio navigation, waypoints are defined mainly through the placement of ground-based radio navigation aids called VHF omnidirectional range (VOR) stations, whose locations determine the airways in a given airspace. Normally, airways begin and end above VOR stations, so these stations represent nodes where large numbers of airways converge and diverge. As a result, it is possible for multiple aircraft flying along different airways and in different directions to find themselves above the same VOR station simultaneously. To avoid this situation, air traffic control must direct such aircraft to separate from one another in altitude or heading before arrival at the VOR station. This means significant reorganization of air traffic and alterations of aircraft flight parameters. Further complicating air traffic control is the regulatory requirement for pilots to fly directly over VOR stations in order to register their flight path and continue along the defined path. This frequently leads to traffic congestion in the vicinity of the VOR

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station. Aircraft may even have to change speed and/or altitude while in holding patterns in order to avoid close-approach conflicts. All these factors can lead to time delays that negatively affect air traffic separation as well as airspace capacity.

Area navigation (RNAV) is a method of navigation which permits aircraft operations on any desired flight path within the coverage of ground or space based navigation aids or within the limits of the capabilities of self-contained aids, or a combination of these. Area navigation denotes generic concepts related to area navigation techniques, and is also one of navigation specifications of ICAO Performance Based Navigation (PBN) concept. Area navigation, which is based on the global navigation satellite system (GNSS), does not require positive identification of VOR station fly-overs; instead, it allows the definition of a large number of virtual waypoints along routes covered by ground-based radio navigation aids, the aircraft's own autonomic navigation system or both. As a result, RNAV can reduce traffic congestion and delays as well as create greater flexibility in route planning. This can shorten flight paths and save substantial costs and time: shortening a route by one nautical mile can save 3,650 nautical miles (6,760 km) annually if 10 aircraft use the route daily. In other words, RNAV can substantially increase flight efficiency, defined as the deviation between the shortest distance separating the departure and arrival points and the actual flight path. Key to this ability to increase efficiency is the ability to reduce conflict situations, in which the air traffic controller must direct aircraft to change course in order to avoid close approaches with other aircraft. Such redirects lengthen flight time and/or trajectory. The average horizontal en route flight efficiency (as an environmental key performance indicator) is the comparison between the length of the en route part of the actual trajectory derived from surveillance data and the corresponding portion of the great circle distance, summed over all IFR flights within or travesting in the European airspace.

The ability of RNAV to increase flight efficiency also means that it can increase effectiveness by reducing costs associated with air traffic management, which are proportional to delay time. As an illustration of the problem of congestions which can cause bottlenecks over significant waypoints in specific airspace, table 1 shows delay costs for different types of aircraft.

Table 1. Low cost scenario cost for common aircraft types (in Euros)

Aircraft type	Delay (minutes)			
	5	15	30	60
B737	110	400	1040	3250
A319	100	400	1040	3320
A320	130	500	1360	4460

Here we demonstrate the ability of RNAV to reduce the number of conflict situations in one airspace sector in FIR Zagreb (Croatia) and thereby increase flight efficiency and effectiveness by shortening flight paths and delay times. This work focuses on RNAV as the original standalone concept, not on some RNAV aspects that have more recently been grouped under the concept of performance-based navigation. Nevertheless, this study could easily be adapted to test aspects of performance-based navigation.

2. RNAV routes in support of air traffic efficiency

RNAV allows aircraft guidance with a certain accuracy without the need for fly-overs of radio-navigation aids. Turns executed during approach provide a good example where RNAV is superior to radio navigation: using RNAV to guide instrumental flight procedures results in narrower buffer areas, such that each aircraft requires less airspace.

RNAV can operate with narrower buffer zones because of its relatively high accuracy of aircraft navigation. Narrower buffer zones mean that more flights can be accommodated within the same airspace sector, increasing airspace capacity and its exploitation. Continuous increases in air traffic in Europe and around the world are driving efforts to optimize airspace and increase capacity. From 2016 onwards, European flight growth is expected to remain at around 1,7% per year. The forecast is for 11,6 million IFR flight movements in 2023, 14% more than in 2016 (for Europa as a whole the most-likely scenario is 50% more flights in 2035 than in 2012).

3. Satellite navigation as a key factor in RNAV

The Single European Sky Air Traffic Management Research (SESAR) framework focuses on the gradual transition from radio navigation to RNAV as the basis for advanced air traffic management and development. As a result, the necessary navigation specifications and corresponding navigation applications rely on satellite navigation. Aligned with this trend, EUROCONTROL strategy for members of the European Civil Aviation Conference predicts that by 2020, the global navigation satellite system (GNSS) will become the primary, and potentially only, system for guiding aircraft navigation. RNAV determines navigation routes based on waypoints defined by GNSS. Global Navigation Satellite System (GNSS) is the collective term for those navigation systems that provide the user with a 3-D positioning solution by passive ranging using radio signals transmitted by orbiting satellites. This system, which comprises one or more satellites, a receiver and other systems for signal correction and monitoring, allows accurate measurement of travel time between a satellite and the receiver, enabling aircraft to determine their positions accurately anytime and anywhere. Currently two independent GNSS systems are in widespread use in civil aviation: the Global Positioning System (GPS), managed by the USA and other countries; and GLONASS (Global Orbiting Navigation Satellite System), managed by the Russian Federation.

4. Simulation experiments

The present study explored the influence of RNAV on airspace efficiency and effectiveness by examining the real case of a bottleneck that occurred above the PUL VOR/DME in one of Zagreb FIR airspace sectors. This bottleneck occurred before the introduction of GNSS-based RNAV, and PUL is the only VOR station in this particular sector. Two scenarios were simulated: the first used routes defined through conventional radio navigation; the second used routes defined through RNAV (Figure 1).

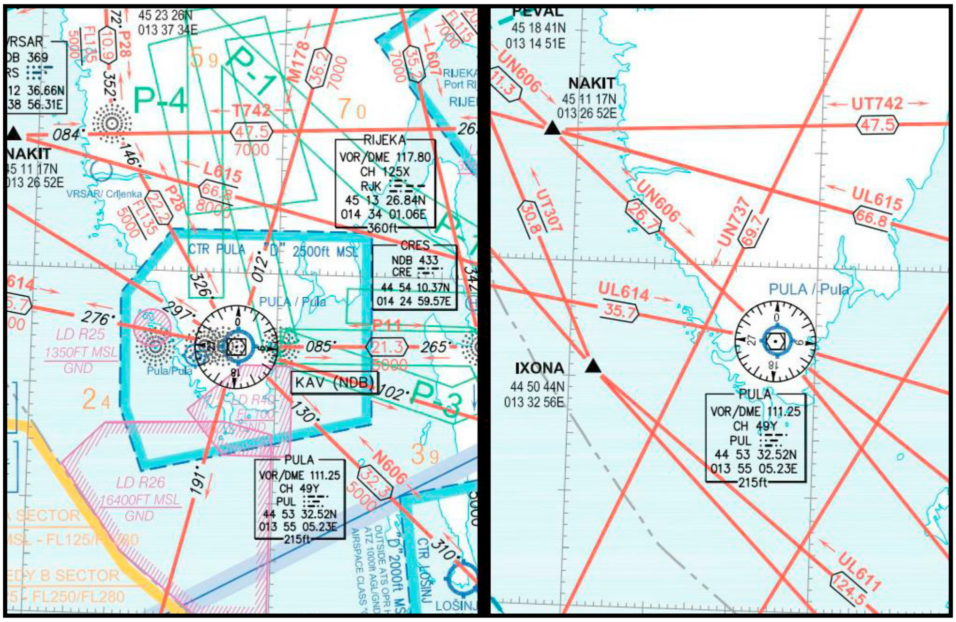

Fig. 1. Air navigation routes used for simulations over PUL VOR/DME

In the first scenario, the air traffic control simulator was programmed with the conventional routes, and the number of aircraft was identical to that on the busiest day of the year before RNAV implementation. Parameters were set to exclude the possibility of RNAV, standard horizontal separation between two aircraft was set at 5 nautical miles, and vertical separation was set at 4000 feet for aircraft flying on the same course or 2000 feet for aircraft flying on different courses. Traffic comprised various types of aircraft operating at different performance levels on various routes, and it was based on a historical traffic dataset involving total of 917 flights, of which 391 passed through the designated airspace sector. Conflicts were recorded when two aircraft approached each other closer than the standard vertical and/or horizontal separations. The simulator issued virtual instructions for changes in course, altitude and/or speed. A total of $C_1(A) = 14$ conflicts were recorded during this simulation.

This simulation was then repeated using a number of aircraft identical to that on the busiest day of the year following RNAV implementation. To explore the influence of increased air traffic, we simulated traffic using a historical dataset involving total of 1522 flights, of which 701 passed through the Upper West sector. A total of $C_2(A) = 43$ conflicts were recorded under these conditions.

In the second scenario, the air traffic control simulator was programmed with the RNAV routes. In addition, the standard vertical separation was reduced to 2000 feet for aircraft flying on the same course or 1000 feet for aircraft flying on different courses, in accord with the principle of reduced vertical separation minima. The first simulation in this scenario assumed the same number of flights as in the pre-RNAV historical dataset (391), and only $C_3(B) = 2$ conflict was recorded. When the simulation was repeated assuming the same number of flights as in the RNAV historical dataset (701), $C_4(B) = 4$ conflicts were recorded.

These simulation results are summarized in Table 2. The results show substantially fewer conflicts in the second scenario when RNAV routes were used.

Table 2. Number of aircrafts and detected conflicts in different scenarios

Scenario	Route type	No. aircraft in sector	No. conflicts
$C_1(A)$	Radio navigation	391	14
$C_2(A)$	Radio navigation	701	43
$C_3(B)$	RNAV	391	2
$C_4(B)$	RNAV	701	4

This reduction in conflicts is expected to result in greater air traffic capacity and shorter flight delays. Following the increase observed already for the past two years, the number of flights affected by ATFM en route delays in the EUROCONTROL area increased further in 2016 from 3,9% to 4,8%. At the same time, the delay per delayed flight decreased from 18,8 minutes to 18,0 minutes in 2016. This increase in airspace capacity reflects the implementation of RNAV routes as well as other measures.

The ability of RNAV to reduce the number of conflicts likely reflects its ability to create additional fixes or waypoints, allowing traffic to be distributed along parallel corridors, each of which serves flights traveling in the opposite direction to flights in the neighbouring corridor. As a result, each pair of intersecting RNAV routes creates four intersections where aircraft must respect so-called semi-circular separation minima and are therefore allocated to odd and even flight levels. This makes conflicts practically impossible, except during overtaking or vertical transitions. It reduces the overall number of conflicts and spreads them out geographically, reducing their density in a given airspace volume. This reduces air traffic controller workload and task complexity, while increasing the capacity of a specific airspace sector and maintaining or even increasing its safety.

5. Conclusion

Satellite navigation can significantly improve the air traffic system. RNAV, which is based on GNSS, can improve efficiency by increasing the number of aircraft entering or exiting the airspace while decreasing the number of close-approach conflicts. At the same time, it can improve effectiveness by shortening delays when flights are re-routed to avoid conflict situations. We demonstrated these advantages of RNAV over conventional radio navigation using simulations of the Zagreb FIR airspace sector in which air traffic levels were based on historical traffic data. Future work should examine airspace efficiency based on direct routes applied in functional airspace blocks, and it should assess results in terms of key efficiency indicators in European transport networks. These indicators include safety, capacity, environment and cost-effectiveness.

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References

International Civil Aviation Organisation (ICAO), 2008. Doc 9613 AN/937 Performance Based Navigation (PBN) Manual, Montreal.

European Organisation for the Safety of Air Navigation (EUROCONTROL), 2013. Introducing Performance Based Navigation (PBN) and Advanced RNP, Brussels.

European Commission, 2013. Regulation (EU) No 390/2013, Official Journal of the European Union, Brussels.

Final report: European airline delay cost reference values (version 3.2), University of Westminster, March 2011.

European Organisation for the Safety of Air Navigation (EUROCONTROL), 2017. Seven-year forecast, Flight movements and Service Units 2017-2013, Brussels.

Groves, P. D., 2013. Principle of GNSS, Inertial and Multisensor Integrated Navigation Systems. Artehc House, London.

European Organisation for the Safety of Air Navigation (EUROCONTROL), 2017. Performance Review Commission Performance Review Report (PRR 2016), Brussels.