CNS/ATM TECHNOLOGIES APPLICATION

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Abstract. The current situation in air traffic management requires new ways of approaches related to insufficient navigation network capacities. The theme is still actual despite the pandemic and war situation, which mitigated the impact of airspace overload for a while. The aim of the article is to present the actual situation, and development of electronic support systems and point up to possibilities of new trends of application at Slovak airports.

Keywords: CNS/ATM; navigation; GBAS system

1. INTRODUCTION

The situation, mostly in the post–war period, significant with the rapid increase of standard air traffic volume, led aviation authorities to search for new optimal solutions for increasing the navigation capacity. Overloaded airspace, insufficient capacity of navigation systems, the complexity of coordination, restrictions resulting from limited airport infrastructure development, noise restrictions, and others, led to the inability to monitor optimal flight paths and have a significant impact on the flexibility of the entire management system.

Conventional navigation infrastructure was not able to handle increasing overload effectively, which caused inefficient flights, delays, higher fuel consumption, flight cancellations, and ineffective air traffic management in general. This situation was contrary to the main aim of air traffic service providers – fast, cost-effective, efficient, and in the first place – safe air traffic management.

For this reason, in order to increase the flexibility of the management and efficient use of airspace, cooperation with future navigation systems based on satellite navigation was being developed. Concepts of RNAV and PBN navigation, an approach with vertical guidance, and an advanced GBAS system, represent a new approach to navigation understanding. Significant delays due to insufficient air space capacity with increasing traffic volume and fragmentation of air space are considered to be the most serious problems in air traffic management nowadays. According to the Central Office for Delay (CODA) analysis from 2019, there was recorded a disproportion in increased delays (273%) versus increased flights (14%) in 2018 [1].

The primal need for rationalization of infrastructure was defined in 1983 as the purpose of the establishment of the FANS committee on initiation of the ICAO organization to solve airspace overload impact to entire navigation management. Gradual transition to advanced systems was represented within the scope of the CNS/ATM concept, which was in interaction with ATM concept development. This resulted in the establishment of collaborative programs known as SESAR and NEXTGEN. The first assumptions about economic savings were quite optimistic, the business case NextGen expected projected benefits of $160 billion between the period 2010 – 2030 [2]. Unfortunately, unexpected Coronavirus disease, lack of risk adjustments, underestimating potential economic downturns, and other risks have a substantial impact on actual projections for NextGen benefits, as reported by the audit conducted between 2019 and 2021 [3].

Extensive research aimed generally at the usage of satellite navigation systems, which are considered to be the primary source of navigation information in the future. Cost-ineffective and outdated systems will be partially replaced and eliminated. Navigation applications tend to RNAV availability on all aircraft according to the PBN manual. The final phase of the flight, which is associated with conventional systems such as ILS and MLS, is considered to be replaced by the GBAS system and SBAS satellite technologies. In the research held at Frankfurt Airport in 2014 related to the noise protection program, the GBAS system proved it's not only economically efficient.

Related to future navigation in general, there is a need to consider the risk of GNSS system outages and consider backup solutions related to conventional systems. One of these is presented in the work [4], using the telemetry method.

2. CNS/ATM CONCEPT

In 1983, the council of ICAO determined that current navigation systems reached their limits and no longer fulfil the need for safe, economical, and fast air traffic management. It led to the establishment of the FANS committee, whose purpose was to identify weaknesses of actual systems and develop new concepts that could overcome conventional systems limitations and help to develop ATM on a global scale. In September 1991, the Tenth Air Navigation Conference endorsed the concept of future navigation, developed by the FANS committee, known as the CNS/ATM concept [5].

The concept represents navigation, communication, and surveillance systems including satellite systems, employing digital technologies with various forms of automatization with the aim to support seamless air traffic management. The main aim of the concept is to foster the implementation of progressive concepts that enable operators to meet required planned arrivals, departures and adhere to preferred flight profiles without compromising safety levels with minimum constraints. The main purpose of the CNS/ATM concept is to provide a comprehensive plan for implementation on global, national, and regional levels with the aim of merging all plans into a unified and coherent strategy [4].

Benefits are based on improving the information transfer and handling, improvement of navigational accuracy, and extending surveillance, which will lead to separation reduction between aircraft, increasing airspace capacity. Advanced ground-based systems allow the exchange of data directly through data links, using flight management systems. This enables improved conflict detection and quicker adaptation to change traffic requirements. The entire ATM system will better accommodate preferred flight profiles and help to reduce flight delays, operating costs, and safety levels [5,6].

Improvements in the field of navigation will include the introduction of the RNAV – navigation along with GNSS – Global navigation systems, which can provide worldwide navigational coverage and are used for non-precision approaches. Cooperation with proper augmentation systems and advanced related procedures could be beneficial for precision approaches. The breakthrough in the area of surveillance is expected to be ADS–B implementation, meaning Automatic Dependent surveillance which enables automatic transmission of the position and other relevant flight information contained in the flight management system via communications links or satellite. CNS technologies will support ATM overall, considering flow management, air traffic services, and flight operations. Integrated ATM systems should fully support the integration and introduction of new technologies through procedures and standards [6].

In 2011, on the purpose of collaborative harmonization between U.S. Nextgen and the EU SESAR program, was signed memorandum MoC – Memorandum of Cooperation. The aim was to ensure global interoperability and harmonization of the two programs [7]. The main elements common for each of them are described below.

2.1. PBN navigation

Performance-based navigation is the new concept of progressive satellite-based navigation concepts, which enables the creation of more efficient and shorter GPS routes in comparison with conventional routes dependent on standard radars. PBN navigation is based on the RNAV – Area Navigation concept. Performance requirements are defined by navigation specifications, in terms of integrity, accuracy, functionality, and continuity for required operation. PBN navigation brings benefits in the way of increased capacity, operational efficiency, improved cost efficiency, and lower environmental impact [8].

2.2. ADS – B Automatic Dependent Surveillance Broadcast

ADS-B is a surveillance technology that provides pilots and controllers with real-time precision and situational awareness. It is considered to be the replacement for conventional outdated systems and transition to tracking based on satellite technology. Information is broadcasted by satellites to receivers, ground stations, and other aircraft. Technology represents benefits in the way of cost efficiency, improved safety, increased level of precision, and possibilities of lower separations [9].

2.3. CPDLC DCL – Departure Clearance

CPDLC DCL technology enables the transition to digital communication between aircraft and control towers. Shortened digital messages in the form of confirmations, procedures, and instructions could shorten the departure process, and eliminate language barriers and misunderstandings between pilots and air traffic controllers [10].

2.4. Localizer Performance with Vertical Guidance – LPV 200

LPV is an instrument approach using different sources of guidance signals than conventional precision systems. The conventional ILS system is a ground-based system dependent on associated transmitters and antennas located on each runway separately, the source of signals for Localizer Performance is the Global Navigation satellite system, which allows simultaneously guiding more aircraft and releasing approaches on multiple locations. The main benefit is increased accuracy and integrity due to GNSS usage [11].

2.5. GBAS system

Ground Based Augmentation system is considered as replacement for conventional ILS systems, based on satellite navigation. It consists of 4 to 6 GNSS signal receivers and a ground unit. The system can cover more runways simultaneously using one single ground device which can increase the capacity of airport runways, increase accuracy due to differential corrections and increase financial efficiency in contrast to an ineffective and demanding ILS system [12].

3. IMPLEMENTATION AND NEW TRENDS IN EUROPE

Implementation of new trends in Europe leads to the usage of GNSS systems and RNAV technology applications aboard new aircraft following the PBN manual. The final phases of the flight which are related to the conventional ILS system, are considered to be replaced by SBAS (Satellite Based Augmentation System) and GBAS (Ground Based Augmentation System).

The first approach to the usage of the GBAS system in regular operation was reached in September 2014, at Frankfurt Airport, as part of a noise protection program. With the intention of decreasing noise levels were applied number of abatement measures. One of them was increasing the glide slope to 3.2 degrees. This abatement helped to reduce noise levels between 0.5 to 1.5 dB (A) depending on the used aircraft type. For test measurements, aircraft types Boeing 747 – 8 and Airbus 319 were used. For an increase of the glide slope, was necessary to install two additional ILS systems on runway Northwest (25R/07L), which ensured flight in higher altitudes in the final phases of the flight. Runway Northwest (25R/07L) thus became equipped with 4 ILS systems, capable of bidirectional landings. As the purchase of 4 ILS systems is cost-demanding, DFS (Deutsche Flugsicherung GmbH) entrusted the airport with the purchase of the Honeywell SLS 4000 – GBAS

CATI system. The 3 September 2014 was launched first GBAS landing, thankfully to which Frankfurt Airport became the first hub airport in the world allowing GBAS landings under CAT I conditions [14,15].

Another key milestone was reached in 2022 under the collaboration of manufacturer Airbus, Lufthansa, and SESAR at the Frankfurt airport again. Through the project DREAMS, the GBAS system was upgraded to GBAS CAT II operations. Frankfurt Airport thus became the first airport in the world to support CAT II operations by the systems GBAS, allowing up to 48 combinations of approach and increasing glide slope to 3,2°. Despite the advantages, the system is still rarely used in navigation infrastructure globally. The condition for the ability to fly GBAS procedures is a Multi-Mode Receiver aboard the airplane that merges several receivers such as ILS, VOR, and GNSS. Nowadays is Multi-Mode receiver implemented into models like the A350XWB, A380, A320, and B787. The rate of aircraft operated at the Frankfurt airport, containing devices, is still low, about 10% [14,15].

3.1. COVID–19 and Ukraine war´s impact on implementation

In the last three years, the European aviation market has had to challenge two major crises. Covid pandemic and war in Ukraine. The devastating impact had COVID consequences in the form of 90% of traffic falling in April 2020, from which is market till now not fully recovered yet. War in Ukraine since 2022 has had another significant impact visible on traffic patterns in March 2022. Regarding EUROCONTROL´s forecast, traffic volumes can continue to recover in the years 2023 – 2024 and could surpass levels from 2019 to 2025 [16].

Paradoxically, the pandemic situation has a major positive indirect impact on PBN implementation. The consolidation of PBN is related to post–COVID economic changes. Several airlines speeded up the process of retirement of aircraft with less GNSS capabilities. Many of them placed orders for new, environmentally more efficient aircraft with improved avionic capabilities, which increased the proportion of LPV capability from 14% to 24% post-pandemic crisis in Europe. Decreased air traffic has provided a chance for continuous work on the deployment of PBN abilities which brings more efficient capacity into the ATM system when traffic volumes return to previous standards [17].

4. POSSIBILITIES OF IMPLEMENTATION IN SLOVAKIA

Major projects of LPS a.s. in the field of flight procedures department in 2021 were the design of flight procedures RNAV 1 SID/STAR and the upgrade of the approach APV SBAS CATI on Airport Košice and M.R. Stefanik Airport [18].

Most small airports in Slovakia are non–public with irregular traffic, without possibilities of satellite approach procedures utilization, without paved airport areas and appropriate lightning. The solution for such an airport could be the use of a virtual tower known as the r-TWR Remote Air Control Tower. The system is mainly developed in northern countries, Australia, and the USA. R - TWR provides full-featured traffic over long distances. Remote control towers use combinations of high technology and high-definition cameras. Air traffic controllers thus have the same information that they would have in a traditional tower. In 2005, was launched project LFV which verified the options of application and economic efficiency of the system. In 2009 was in Sweden Malmo controlled the first flight from the Angelholme airport in the range of 100 km and back. The project was included in the SESAR program. Despite increased requirements on concentration and attention of air traffic controllers, the ability of spatial attention was not affected and the workload remained within a safe level [19].

How we can proceed with implementation on the biggest Slovak Airports? As we stated GNSS technology is predetermined to become the main positioning system to optimize conventional infrastructure. M. R Stefanik Airport´s infrastructure consists of two perpendicular runways. The main runway is runway 13 – 31 with a precision approach CATIIIA and runway 04-22 with a precision approach CATI. The navigation infrastructure of the airport is shown in Figure 1.

Current navigation infrastructure contains:

- ILS CAT I – LOC 22(OKR), ILS – GP 31,
- ILS – GP 22; ILS CAT IIIA – LOC 31(OB),
- DME (OB), VOR/DME (JAN), DME (OKR),
- NDB (OB), NDB (OKR),
- L (B), ¬ OM, MM [20].

Current precision approaches are the following :

- RWY 31: NDB – DME, ILS CAT II/IIIA, ILS CATI, RNAV GNSS, LOC,
- RWY 22: NDB – DME, ILS CATI, RNAV (GNSS), LOC [20].

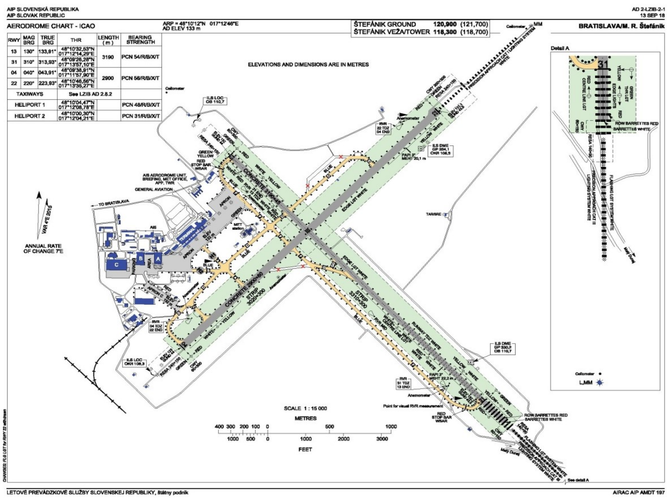

Figure 1 M.R. Stefanik Airport – navigation infrastructure [20]

For decades of usage, the ILS system proved its functionality and reliability, but its disadvantages in the form of economic inefficiency, sensitivity to the operation of other vehicles in sensitive areas, the possible impact of topography, related operational limitations, and others predetermine its replacement by GBAS system.

The main advantages of the GBAS system are based on its structure, which consists of one ground station and 4 to 6 reference signal receivers able to cover more runways. This allows the operation of approach precision CATII/III on both runways by one system. Despite this, the ILS system has to be installed for each runway separately.

The functionality of a conventional ILS system can be affected by topography, barriers, vehicle operation, and other aircraft. Due to this reason is defined sensitive area. GBAS system, using satellite data transmission does not require the definition of any sensitive area. Applying differential corrections to the GBAS system increases accuracy and safety levels. GBAS system means in general increased runway infrastructure capacity, flexible flight path, extended touchdown points, approach directions, and angles, shortened and steeper approaches, reduced maintenance cost due to weight distribution among runways, elimination of delays, reduction of operational costs, noise reduction and also related CO_2 production elimination.

Considering M.R. Stefanik's rationalization and application of GBAS on runways we used financial data from the Analysis of the implementation GBAS system at Vaclav Havel Airport [21].

As the analysis was done in 2013 we have considered the rate of inflation in the Slovak Republic which is approximately 25% [22]. Inflation development is shown in the picture below:

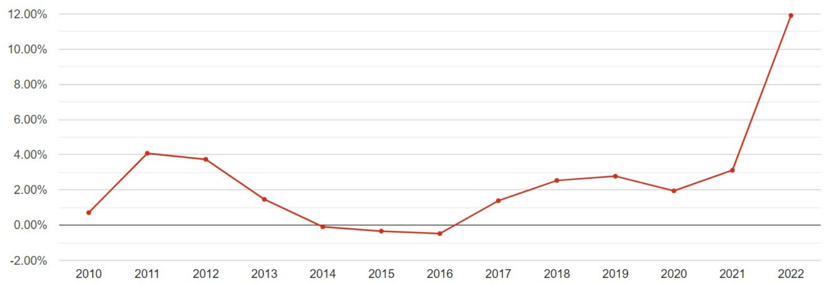

Figure 2 Inflation rate development [22]

The approximate cost of the navigation infrastructure of M.R. Stefanik Airport represents the amount 1 920 000€, from which DME / ILS CAT I costs 920 000€ and DME / ILS CATII/III costs represent 1 000 000€, including calibration, construction, and installation. Estimated early operational cost including maintenance costs, equipment tests, and spare parts takes 230 000€ as shown in Figure 3 below [21].

Operational costs	*Price (€)*
GBAS CAT I	53 750
GBAS CAT II	53 750
ILS CAT I	98 750
ILS CAT II/III	131 250

Figure 3 Operational costs [21]

Considering future infrastructure using the GBAS system, we have to take into account the vulnerability of GNSS systems in case of ionospheric interference, constellation, and interferences and try to design a network with reverse mode in case of GNSS outage. For M.R.Stefanik Airport can be considered two concepts, assuming the replacement of systems separately with conventional ILS systems as reverse mode option.

4.1. Replacement of ILS CAT I on the runway 04 – 22

In the first case, we replaced the ILS CATI system with the GBAS CATI system and left the conventional ILS CAT II/III A system as a reverse mode option on runway 13-31. Set-up costs, as we can see o picture 3, are contrary to conventional ILS CATI lower, making the difference of 52 500€. Operational cost, in comparison with a conventional one, is also lower, representing a difference of 45 000€ [23].

4.2. Replacement of ILS CAT II/III A on the runway 13 - 31

In the second case, we assumed the replacement of the ILS CAT II/III A system by GBAS CAT II/III. In this option, set - up cost of the GBAS system is significantly higher than the conventional, making a difference of 452 500€. Operational costs are on the contrary higher in the case of conventional ones, representing a difference of 77 500€ [23]. Set-up costs, including installation, certifications, and civil works are shown in Figure 4 for GBAS infrastructure, and in Figure 5 for ILS infrastructure.

GBAS INFRASTRUCTURE	*PRICE (€)*
GBAS CAT I	625 000
INSTALLATION	150 000
CIVIL WORKS	55 000
CERTIFICATION	37 500
TOTAL	867 500
GBAS CAT II & III	1 250 000
INSTALLATION	150 000
CIVIL WORKS	55 000
CERTIFICATION	37 500
TOTAL	1 492 500

Figure 4 GBAS infrastructure costs [21]

ILS INFRASTRUCTURE	*PRICE (€)*
DME, ILS CAT I	420 000
INSTALLATION	218 750
CIVIL WORKS	243 750
CALIBRATION	37 500
TOTAL	920 000
DME ILS CAT II / III	500 000
INSTALLATION	218 750
CICIL WORKS	243 750
CALIBRATION	37 500
TOTAL	1 000 000

Figure 5 ILS infrastructure costs [21]

The price difference in the second case – 452 500€ could be overcome as shown in the timeline in Figure 6 below, in 6 years.

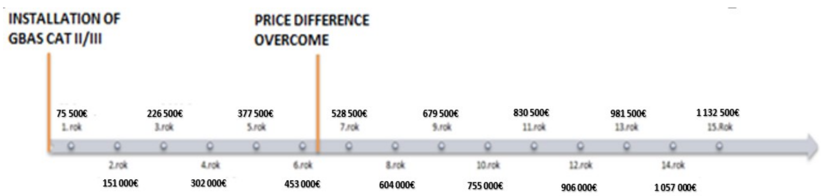

Figure 6 Price difference overcome

5. CONCLUSION

The situation after the post-war period required new approaches to the whole air traffic management system. Insufficient capacity caused significant delays, inefficient operations, increased fuel consumption, and related environmental impact. Aviation authorities tried to mitigate the negative impact by launching new projects with the main aim of satellite systems. Satellite systems seem to be one perspective solution for future navigation concepts with the gradual elimination of outdated systems. The application of new technologies was sequentially applied to many airports and air traffic management procedures, which was unexpectedly interrupted by the pandemic and war situation over the last three years. The aviation market thus has to challenge the biggest crisis from the last decade with a devastating impact on traffic volumes and overall revenues. Traffic volumes are expected to surpass previous levels in the next years. Paradoxically, this situation has a positive impact on future systems implementation in the form of the speeded process of retirement of old aircraft without GNSS capabilities. The situation in Slovak airports could be, in our point of view, improved with progressive GBAS systems and remote control towers in the case of small airports. Simulation, with respect to the inflation rate in terms of the Slovak market, shows cost efficiency in contrast with the ILS system, which, except cost saving, can bring benefits in terms of increased airport capacity, reduced maintenance costs, more efficient approaches, noise, and environmental impact reduction.

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