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MEASUREMENT OF GNSS INTERFERENCE AT AIRPORT ZILINA

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Abstract

The paper described the problems of GNSS interference measurement at airport Zilina. The Global navigation satellite systems (GNSS) are widely used both for civilian and military operations to determine the location, speed, acceleration, and trajectory of the user on the ground. GNSS refers to a constellation of satellites that provide signals from space transmitting positioning and timing on data receivers. The intentional errors include jamming and spoofing which are caused by systems sharing the same frequency illegally. The method for measuring signal interference is defined by the parameters that affect the calculation of the position of interest. Monitoring the extent of the interference and its impact is a necessary procedure for the successful management of aircraft operations at the airport.

Keywords

GNSS, GPS, GLONASS, interference measuring, EGNOS

1. Introduction

The problems of measuring GNSS interference is very complex, because are necessary know of the type of source interference and potential hazard impact on CNS equipment infrastructures.

Global navigation satellite systems (GNSS) are widely used both for civilian and military operations to determine the location, speed, acceleration, and trajectory of the user on the ground (Rostáš & Škultéty, 2017). GNSS refers to a constellation of satellites that provide signals from space transmitting positioning and timing on data receivers (Curran et al. 2016). The US Global Positional satellite (GPS) provides a global position and time determination to both civilian and military operations. It relies on the world geodetic system (WGS) to offer geographical coordinates. The Russian GLONASS and the European Galileo are used in civil aircraft operations (ICAO 2012). The ability of the signals to create their solutions is subject to several sources of disturbance which cause errors in the measurements processed by the receiver. These errors damage positioning accuracy (Gao, Sgammini, Lu and Kubo 2016). Earth receivers may sense signals and build navigation solutions from more than one satellite at any particular time.

As the GNSS signals approach the ground, their power and chip rate diminishes and assumes a short period of Pseudorandom Noise (PN) codes making it susceptible to interference by electromagnetic signals. These interferences are either intentional or unintentional. The intentional errors include jamming and spoofing which are caused by systems sharing the same frequency illegally. Other causes are attributed to signal components such as intermodulation, dispersion and harmony emerging from radio broadcasting and communication emitters. The other source is the leakages of electromagnetic radiation in the navigation frequency band resulting from electronic equipment (Novák, Havel and Bugaj 2018). Often, harmonic challenges the stability of GPS band signals. The unintentional sources of interference emerge from suppressing jammers which makes the receiver unable to yield PNT results. The spoofer which makes the receiver give false results, and hence necessitates the use of GLObal Navigation Satellite System (GLONASS) to identify and measure the errors. Since human activities cause intentional interference, the determination of the location, transmission power and boot time are variable which makes it hard to examine.

2. GNSS interference measurement methodology

The method for measuring signal interference is defined by the parameters that affect the calculation of the position of interest. As a result, identifying the interfering signal and the associated effects on the GNSS is vital. The GNSS signal strength is different for each of the constellation systems, whether it is GLONASS, GPS, or Galileo. Also, critical locations of the broadcast signal are different for different systems (Novák, Havel and Bugaj 2018). The GNSS references use the difference in the time of travel of radio waves from at least four satellites to fix the position of the receiver and get an accurate value for time. By principle, the timing synchronization identifies areas that are vulnerable to jamming of the GNSS references. Necessarily, the preamble timing synchronization and the parity check are vulnerable to jamming interference (Yang, Kang, Kim and Park 2012). According to Curran et al. (2016), measuring the extent of jamming interference depends on the output of the sensitive areas and the transmission time during navigation as summarized below figure 1.

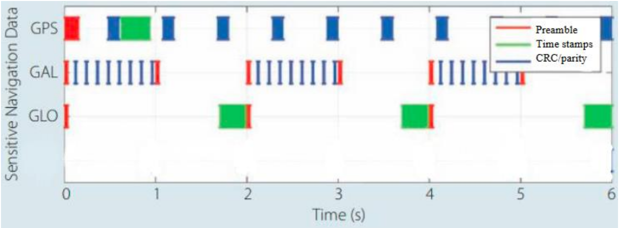

Figure 1: The sensitive navigation data during the time. Source: Adapted from Curran et al. 2016.

Fundamentally, the measurement of the GNSS signal interference requires examination of the effects of errors on all systems, including GPS, Galileo and GLONASS. The process is accompanied by an estimation of the degree of the GNSS to identify the location of the disturbance signal. As a result, measuring GNSS interference requires the definition of the type and intensity of the attack and the position of the source of the disturbing signal (Novák, Havel and Bugaj 2018). The type of attack is defined based on whether it is a simple jamming or a sophisticated attack such as spoofing and meaconing.

Figure 2: GPS jammer from e-shop. Source: Authors.

Through a multidirectional focusing using an antenna with a narrow directional aspect can help identify the location of the source of disturbance, especially for the unitary source of interference. However, for multiple sources, it is necessary to distribute the sources and classify them according to intensity and frequency. To measure the position efficiently, determination of the position of the antenna in the space is the starting point (Yang, Kang, Kim and Park 2012). The most appropriate method to estimate this position is to use the GNSS signal which is less vulnerable to interference. Inevitably, this process will help identify the GPS and Galileo interferences whose configurations depend on the form of initiating GNSS reference. As for the GLONASS, either GPS and Galileo can apply, thus establishing the interdependence that exists between the GNSS constellation systems.

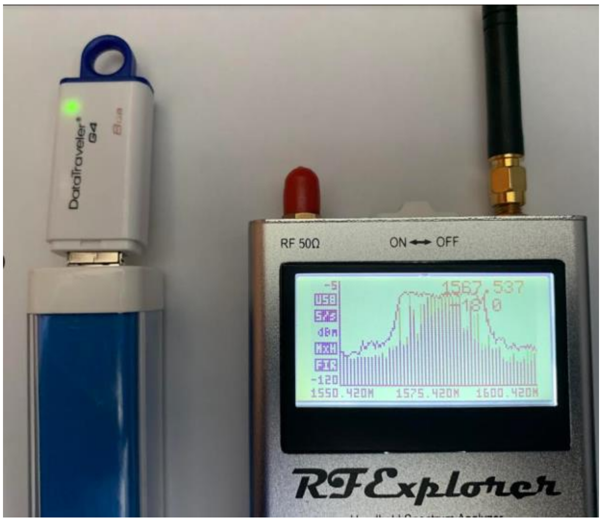

Figure 3: The GPS L1 jammer output power -18dBm. Source: Authors.

Jamming arises when the GNSS receiver receives stronger signals of the same frequency from the other device that overlaps the intensity necessary from the satellite, leading to the unavailability of the system. In order to monitor these errors, the ground system must identify these interferences early enough and design mitigation procedures (Isoz, Akos, Lindgren, Sun and Jan 2011).

Figure 4: The GPS L1 and L2 jammer output power -19.5dBm. Source: Authors.

The other method to measure and mitigate GNSS interference is by receiving and delaying the signal transmission at a set frequency to space by a given time interval. This process confuses the navigation system to provide the inaccurate location of the aircraft. Often, the signal from the delayed line detailing the GPS characteristics that establish hangers, and tunnels with the facility help in crowding out the GNSS interferences and isolating them according to the interface in use.

3. Measuring at Airport Zilina

The development of ground stations that monitor interference is not only hard but also ineffective to singly detect and measure interference of the GNSS reference. Usually, the ground receivers and antenna are unable to cover the entire airport surrounding as well as identify all sources of disturbance due to their short frequency. Subsequently, the installation of a flight laboratory helps in the detection, tracking and measurement of the extent of disturbance over a short period of time to enable the location of the position.

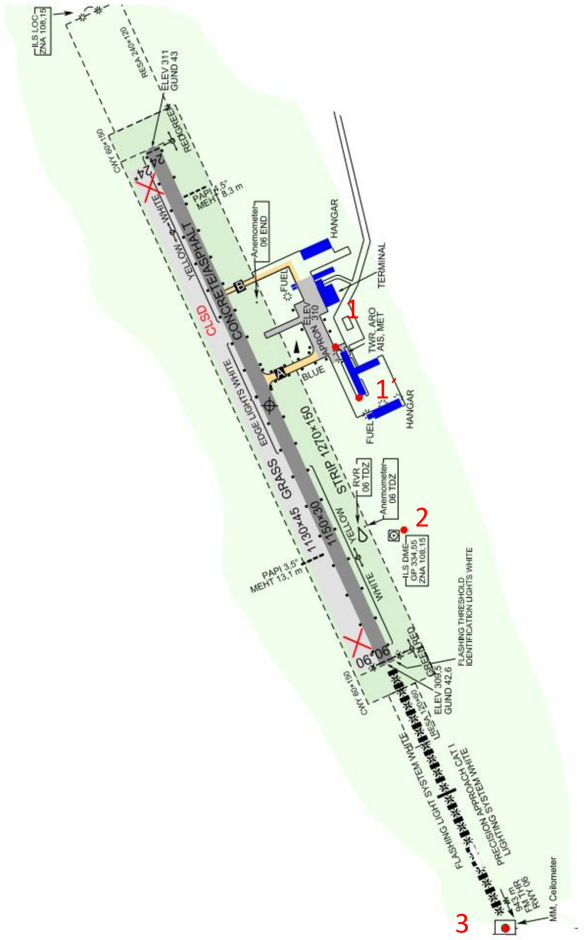

Figure 5: The local maps of the airport Zilina, with potential point for measuring GNSS interference. Source: Authors.

The measurement of GNSS interference at airport Zilina needs two antenna installed at the corner of the airport (Figure 5, position n. 1 and 1´). The other possible installation point is on ILS/GP mast or inner marker (IM) mast (Figure 5., position n. 3).A GNSS antenna that receives signal interferences from the satellite is set outward orienting to receive satellite signals and is installed at a corner in the airport. The other antenna is installed on top of the flight fuselage which helps when the aircraft is approaching the airport. GNSS antennas on aircraft will pick up signals generated from the space and will help during the determination of the position of the user during signal interference. In any case, there is interference; the position of the aircraft is determined based on the conventional ground equipment VHF omnidirectional ranges (VOR) with Distance measuring equipment (DME). During the full spectrum, GPS, GLONASS and Galileo are not consistently disturbed, instead, a single system is used to establish the magnitude of the disturbance (Hoffman 2001). For instance, during GPS interruption, the Galileo system will be used while others will not be considered. It is during the interruption that the direction and nature of the disturbance are measured and recorded. Essentially, the procedure requires monitoring of the signals from the EGNOS L1 satellites in order to determine the integrity of the interference. Subsequently, manual evaluation of the recorded results is undertaken to measure the extent of the interference.

4. Conclusion

Interference poses critical threats to station receivers of GNSS reference. It helps address more professionally safety measures in the airport as well as other processes that rely on GNSS references to determine location and position. Monitoring the extent of the interference and its impact is a necessary procedure for the successful management of aircraft operations at the airport. The antenna used at the ground should actively detect, characterize and communicate the impact on the overall sustainability of the airport operations. The three types of GNSS references, including GPS, GLONASS and Galileo rely on the stability of the receivers to record and read, absence of other instruments with unique electromagnetic effects. The receivers not only collect but may also determine the extent of the disturbance caused by the source. The method of measuring interferences of the GNSS references starts with the identification of the intentional and unintentional sources of disturbances and ends with the determination of the most efficient technical specifications with the ability to detect, record and measure the interference. As a result, to detect, identify, and measure the extent of interference on the GNSS constellations at Zilina Airport, a framework consisting of antenna and receivers is necessary.

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INTEGRATION OF UTM WITHIN THE CURRENT AIRSPACE ARCHITECTURE. IS IT EVEN POSSIBLE?

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Abstract

This paper comprehensively describes the various issues of Unmanned Aircraft Systems (UAS) in terms of their integration into a contemporary and complex system such as Air Traffic Management (ATM). In its introductory part, the paper systematizes and outlines the theoretical knowledge of UAS and categories of airspace sharing entities. However, the main part is devoted to the analysis carried out on the observation of latest proposals of Unmanned Aircraft Systems Traffic Management (UTM), new flight rules as well as state-of-the-art research in several countries throughout the world. The objective of this task is to assess the possibilities, obstacles, and approaches to the integration of unmanned aerial vehicles (UAVs) into the current airspace. The content of this paper is not only informative in nature it but offers concrete explanations, and it may be used as a part of preliminary study for further research in this area.

Keywords

UTM, integration, UAV, ATM, airspace

1. Introduction

The digital age of aviation will change our skies. The number of flights will grow by orders of magnitude. The Airports of tomorrow will be around us, e.g. in our homes and our workplaces, on the roofs of buildings, on top of delivery vans and fire trucks. However, such dramatic expansion is not so straightforward. We must find a way to introduce these aircraft safely. They must co-exist with each other and with future uses that have not been invented yet. It's necessary to redesign airspace in a way that enables innovation, while also prioritising high assurance. The benefits of one flexible architecture – the Internet, for example, is possible only in the online world. There are multiple proposals for modernizing airspace using digital systems. NASA's UAS Traffic Management (NASA UTM) creates a framework for safely managing a growing use of low-altitude airspace. In Europe, the SESAR Joint Undertaking is developing „U-Space" which opens the continental market for lower altitude drone and aircraft services. Both plans paint a picture of a decentralized, coordinated network of services that safely open airspace to new and exciting uses. Recent developments in battery capacity, autonomy and on-board technology makes operation of completely new kinds of aircraft possible. These aircraft have new shapes, capabilities and roles, which our current airspace system was not designed to handle. Smaller cargo drones can move packages faster and more efficiently to destinations like hospitals, offices and homes. An emerging class of electric vertical take-off and landing (eVTOL) aircraft can transport people around congested cities in minutes, instead of hours. These new vehicles can fly higher or lower than ever before. And because prices will fall to a fraction of today's air operations, they create the potential for massive, wide-scale use.

2. Background and state of the art

The term Unmanned Aircraft System – UAS was adopted by the International Civil Aviation Organisation simultaneously with the British Civil Aviation Authority after it was adopted by the United States Department of Defense and the FAA in 2005 (Jcs.mil, 2019). This term emphasizes the importance of elements other than the aircraft itself. It includes elements such as ground control stations, data links and other support equipment. Recently adopted terms are unmanned-aircraft vehicle system (UAVs), remotely piloted aerial vehicle (RPAV) and remotely piloted aircraft system (RPAS).

2.1. Categories of airspace sharing entities

It is obvious that main users of the today's skies are manned jet airliners flying for commercial purposes and ever-present general aviation airplanes and helicopters. However, this is about to change due to the enormous amount of unmanned aircraft expected to be operating in the next few years.

2.1.1. Commercial aviation

IATA (2019) predicts that airspace will get busier and more complicated as unmanned operations expand and global air traffic doubles by 2036. With up to 25,000 commercial flights in the air during peak times, demand for pilots will triple current numbers and greater ATM automation will be necessary to handle the increased volume.

2.1.2. Helicopters

Helicopters excel when endurance or capacity are important—such as in emergencies, search and rescue, commercial transport, and maintenance of infrastructure. Today's helicopters predominantly use visual flight rules but are increasingly adopting digital systems for navigation and air traffic coordination (NASA, 2018).

2.1.3. General aviation

Private, non-commercial flight covers everything from high-performance business jets and medical transports to gliders and flight trainers (Kazda et al., 2013). Pilots require flexibility in when and where they fly, generally depart without filing a flight plan, and may seldom talk to air traffic controllers, depending on where they fly. In general, the community is cost-conscious, against new equipage mandates, and concerned about privacy, so should only be required to participate in the air traffic system when it is a safety issue. Several groups hold considerable sway, particularly when it comes to imposing taxes or usage fees.

2.1.4. Hobby UAVs

More than 3 million consumer hobby drones were sold worldwide in 2017. Users fly for fun, and most flights are remotely controlled, while some newer drones can automatically follow the user or fly pre-programmed patterns. Hobby pilots are required to stay below 400 feet above ground level in most areas, but this is currently difficult to enforce. Most users are untrained, relying on education from pamphlets or programs like the FAA's Knowbeforeyoufly.org (2017).

2.1.5. Imaging and analytics UAVs

Drones can perform inspections and capture imagery faster, more often, and more safely than terrestrial scanning (Pecho, et al., 2019). This data can be used for everything from construction and agriculture to insurance and disaster relief. Flights can cover a region on a regular schedule or be ordered on demand. These missions can be local or cover long distances (Ažaltovič & Kandera, 2018).

2.1.6. High altitude long-endurance UAVs

Whether they are remotely piloted or fully autonomous, they are able to operate in very high altitudes, above altitudes used by airliners or business jets and for long periods (Bugaj et al., 2019). They could provide services such as sub-satellite imagery and distribution of access to wireless internet.

2.1.7. Delivery UAVs

Four billion parcels were ordered online for home delivery in Europe in 2017, up 28% on the previous year (Ažaltovič & Kandera, 2018). Tomorrow, everything from retail parcels to urgent medical deliveries will be moved by air—from small drones to larger eVTOL transports. Delivering only 1% of parcels this way will create more than 14,000 drone flights every daylight hour across Europe alone, requiring significant airspace management to ensure safety.

2.1.8. Government and military

National and regional governments regularly use airspace for law enforcement and emergency management. They use light aircraft, helicopters, and drones. Military training and operations, meanwhile, use aircraft and drones extensively (Jcs.mil, 2019). It is important that government and military operators receive priority access to airspace when necessary. They should also be able to enact airspace restrictions, define training routes, and mandate other airspace constructs that are essential to public safety and national security missions.

2.1.9. Transport UAVs

Today, light planes and helicopters connect air taxi operators and passengers through platforms like Airbus' Voom and Blade. Air Mobility (UAM) aircraft will take off and land vertically from airports and "vertiports" all over towns and cities for passengers and emergency transport. As the technology becomes more affordable, air traffic will increase hundreds of times over. If just 1% of the 2.2M people in central Paris commute by UAM each day, there will be more than 11,000 flights per hour over the city during peak times as is predicted by Airbus (2019).

2.2. Infrastructure and development

Industries ranging from agriculture to entertainment and media are taking full advantage of the benefits drones offer. However, it's clear that one of the most rapidly growing sectors is infrastructure development which includes construction. This isn't surprising, as their benefits range from on-site safety to a level of project monitoring which wasn't previously possible. The market potential and business case are exemplified by large data processing contracts that exceed EUR 10 000 annually for a single drone used across multiple sites given drones enable routine surveys over large areas in a timelier efficient and cost-effective manner. In the near term, mining is likely to drive significant growth with 7 000 drones expected across around 20 000 quarries and mines that are mostly small (i.e., 15 000 sites have approximately 3 employees). The number of drones in a variety of construction sites is likely to be much larger, estimated at 35 000, especially once drones can operate closer to populated areas (Geospatial World, 2018). The expected operating model within construction is for individual surveyor teams to be allocated a drone. 35 000 drones are expected to be needed to serve a large proportion of over 2 million estimated construction sites in Europe given each team has the ability to serve multiple sites (estimated at 8 per team) that each need support for a portion of the total duration (requirement of 3 months, acknowledging different usage intensities across sites, as part of sites that may last beyond a single year).

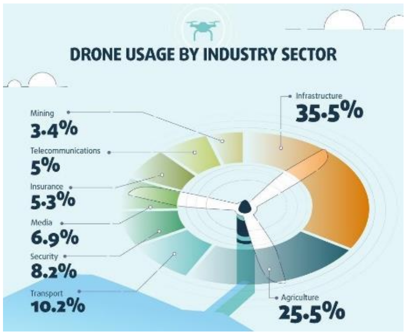

Figure 1: Largest operators of commercial drones. Source: (Geospatial World, 2018).

3. Process of UAS integration

Small UAVs are unmistakably different from aircraft in so many ways, yet they are considered as full-fledged aircraft in most countries. This is perhaps the prime challenge impacting their governance. Few understood how the UAV industry could reinvent itself so dramatically and become so far reaching in every enterprise and field of work. The number of UAVs now flying is mind-boggling. The yearly sales of small UAVs in 2016 have reached 400 000 units in Germany and are likely to reach 1 million in the next year, 2020 (Sesarju.eu, 2019).

Many urban areas including airports and helicopter landing sites and their associated approach/departure paths need to be safe from the interference, as aviation is not without risk and the reputation of UAV technology would be severely affected in the aftermath of a mid-air collision with a passenger aircraft. Also, beneficial civilian applications of the UAS have been proposed, from goods delivery and infrastructure surveillance, to search and rescue, and agricultural monitoring. Currently, there is no established infrastructure to enable and safely manage the widespread use of low-altitude airspace and UAS operations, regardless of the type of UAS. A UAS traffic management (UTM) system for low-altitude airspace may be needed, perhaps leveraging concepts from the system of roads, lanes, stop signs, rules and lights that govern vehicles on the ground today, whether the vehicles are driven by humans or are automated.

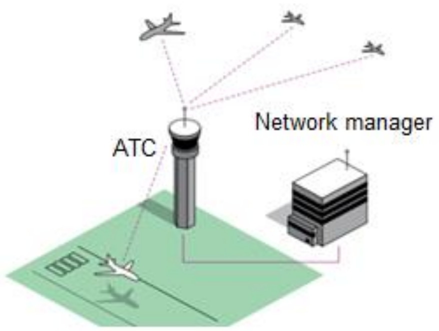

Figure 2: Current ATM system. Source: Authors.

UTM allows the same foundation to serve different needs in different geographies at different times. Regulators can adapt requirements to match their local needs, and operators can select the providers they need to complete their missions. Providers can create, update and deploy their own services quickly. One operator can choose to build, certify and supply its own services, while another may find the same services in a marketplace. Providers will be responsible for coordinating with each other. For unmanned applications to thrive, many stakeholders must come together to advance their respective domains. Advances can be accomplished in phases, with each phase dependent on the previous ones. As UTM shows positive results, there may be technology sharing or increased integration with traditional ATM.

3.1. UTM by NASA

Building on its legacy of work in air traffic management for crewed aircraft, NASA is researching prototype technologies for a UAS Traffic Management that could develop airspace integration requirements for enabling safe, efficient low-altitude operations. While incorporating lessons learned from the today's well-established air traffic management system, which was a response that grew out of a mid-air collision over the Grand Canyon in the early days of commercial aviation, the UTM system would enable safe and efficient low-altitude airspace operations by providing services such as airspace design, corridors, dynamic geofencing, severe weather and wind avoidance, congestion management, terrain avoidance, route planning and re-routing, separation management, sequencing and spacing, and contingency management (NASA, 2018).

3.2. U-SPACE for Europe

U-space is a set of new services and specific procedures designed to support safe, efficient and secure access to airspace for large numbers of drones. These services rely on a high level of digitalisation and automation of functions, whether they are on board the drone itself, or are part of the ground-based environment. U-space provides an enabling framework to support routine drone operations, as well as a clear and effective interface to manned aviation, ATM/ANS service providers and authorities. U-space is therefore not to be considered as a defined volume of airspace, which is segregated and designated for the sole use of drones. U-space can ensure the smooth operation of drones in all operating environments, and in all types of airspace (in particular but not limited to very low-level airspace. It addresses the needs to support all types of missions and may concern all drone users and categories of drones (Sesarju.eu, 2019).

Key functions are provided by U-space Service Providers (USP) which may be required to exchange certain information and coordinate through a SWIM system. They may also communicate with a U-space system manager—similar to the Single European Sky’s current network manager. This acts as a centralized coordinator in a manner much like NASA’s FIMS, as well as manages traffic. Other providers are responsible for non– safety–critical services, as well as data on weather and terrain (Airbus, 2019).

3.3. UOMS in China

The UOMS is an integrated system serving as a Chinese solution of offering air traffic service to UAS. It cooperates with GAFS system and communicates with current ATM system. Except the role in air traffic service, UOMS also interacts with other UAS management systems developed for public or military purpose. In order to integrate unmanned aircraft into the ATM, the proposal is divided into two levels. On the strategic level, the priority should be solving airspace classification and configuration problems, while on the tactical level it should be providing different air traffic services to different users (Butterworth-Hayes, 2019).

Current ATM should transmit to UOMS the flight path of the transport aircraft in terminal (approach) control area, in order to provide the basis for the required task approval and real-time collision risk alarm for UOMS. Due to natural physical isolation, ATM does not need to transmit the en-route flight path of the commercial flight. UOMS should transmit to current ATM all flight plans (except open operations) received by UOMS and real-time UAS flight data, including real-time latitude and longitude, altitude, speed, course, flight identification, etc.

3.4. JUTM

The name is derived from the initial of Japan Unmanned System Traffic & Radio Management Consortium. In the United States, UTM activities for unmanned aerial vehicles are being conducted mainly by NASA, while JUTM is examining land and air unmanned aerial vehicles and also including radio wave management. Their main goal is to create a new, industrial „Drone Innovation Space“ and promote the ongoing revolution in aviation. They also aim to incorporate Japan's systems and technologies to the international standard that NASA'S UTM project is pursuing (Jutm-imgtransuv.org, 2018).

This system is being built by the JUTM (2018) and a national UTM project founded by New Energy and Industrial Technology Development (NEDO). It comprises one FIMS, several UASSP providers, a layer of SDSP providers, and operators. FIMS manages all flight plans, handles emergency alerting and provides avoidance instructions. The UASSP sits between FIMS and each operator. JUTM started demonstrations in 2017. Individual systems developed under NEDO will be demonstrated during 2018, with first full system demonstrations in 2019 and implementation slated for the 2020s.

3.5. Global UTM Association

The Global UTM Association (GUTMA) is a non-profit consortium of worldwide Unmanned Aircraft Systems Traffic Management stakeholders. Its purpose is to foster the safe, secure and efficient integration of drones in national airspace systems. Its mission is to support and accelerate the transparent implementation of globally interoperable UTM systems. GUTMA members collaborate remotely. The purpose of this association is to:

- identify actions to be taken to safely, securely and efficiently integrate UAS into national airspace systems,
- draft and distribute an interoperability blueprint for traffic management of UAS,
- collaborate with regulators and other stakeholders worldwide to identify standards, as well as scalable and compliant technical solutions to the development of UAS traffic,
- instigate and facilitate partnerships between manned and unmanned users of the airspace,
- and engage with other associations and groups facing similar challenges.

The Association may engage in all activities and take all actions necessary and appropriate to carry out the above objectives (Global UTM Association, 2017).

Among their publications, the UAS Traffic Management Architecture. This document describes the overall high-level UTM architecture. It considers all types of UAS operations (VLOS, EVLOS and BVLOS), and covers the needs of both RPAS (piloted) and autonomous unmanned aircraft. The scope of the UTM described in this document will focus on a UTM solution for UAS operations in very-low-level airspace. The document also addresses the requirements for all phases of the flight and is identified as a common architecture with interfaces with external systems. This will serve as a baseline to define the standard interfaces.

3.6. MyDroneSpace by IXO Systems

In more congested airspace of countries like Hungary a Poland, it is not yet possible to integrate a delivery service on such a scale as in Rwanda. Civilian hobby use is so far the main goal of companies such as R-SYS Ltd. with their IXO System which represents a complex solution for airspace users and providers who look for a product that seamlessly integrates information on manned and unmanned aircraft operations and provides real-time aeronautical information for all airspace users. The system applies the latest regulations to flight planning, airspace usage conflict calculation, RPAS flight validation/clearance processing, manned/unmanned aircraft management, or aeronautical data provision. IXO SYSTEM presents a powerful and multi-platform solution which satisfies requirements of ATM integrated and interoperable system while it emphasizes timely distribution of accurate aeronautical data. It aims to:

- provide information via web interface to various users within and outside ANSP network,
- facilitate the NOTAM Office daily operations, to maintain and exchange NOTAM information,
- grant demands of ANS providers,
- publish and update AIP information
- provide ARO with integrated flight planning information,
- provide RPAS (Drone) flights management tools. (R-SYS, 2018)

Figure 3: Requesting flight zone for an activity. Source: (R-SYS, 2018).

3.7. DroneRadar

A rapidly growing number of Unmanned Aerial Vehicle operations have caused major concern over flight safety. Air Traffic Management institutions, like ATC, FIS are finding it difficult to track such operations as the majority of those are conducted by amateurs with no aviation background and little or no knowledge of both airspace structures and flight rules. The aim of the DroneRadar is to vastly improve airspace safety by providing a simple, available to all solution to performing, monitoring and integrating UAV operations with the manned aviation flow in European airspace.

DroneRadar (2016) is a non-restrictive, mobile, cloud-based platform which allows the precise registration and monitoring of drone operations via social sourced information. The system is based on simple concepts easily understood by amateurs but at the same time provides sophisticated functionality for Air Traffic Services and for professional users such as military and governmental institutions. Up to now there has been no means or concept of integrating such operations into the mainstream ATM flow, which would allow for creating awareness of them and their monitoring. DroneRadar is the first, ANSP integrated system platform allowing for such integration.

Clearly, DroneRadar is a solution many UAV operators and ATM institutions have been waiting for and has enormous potential for structuring procedures needed to integrate UAV operations into the ATM flow. Detailed analyses of the collected statistics may be used for risk assessment and may be a great input for SMS (Safety Management System) analyses. DroneRadar confront all regulations which apply to FIR and present them in easy to understand way, to all users (professionals and amateurs). The service is fully operational in Poland since December 2015.

4. Findings and recommendations

In order to support the safe integration of unmanned aerial systems into current airspace, several recommendations and findings have been made. Today's Air Traffic Management systems are complex and consist of many different functions. They are provided in a one-to-many fashion, through a central entity such as a control centre, and the services are deployed as a solid framework. Functions include the acceptance and approval or rejection of flight plans, tracking of aircraft, providing guidance and separation services to pilots, and handling emergency situations. This approach works well for existing aviation needs, which are well defined and grow predictably. New traffic management systems will perform many similar functions. However, the way these are delivered will need to be different because of the radical increase in traffic density and the changes in vehicle performance, onboard automation, and sensing technology. For example, while most commercial flights are planned (in advance) and follow regular schedules, air taxi and cargo missions can be requested just minutes before take-off. In urban environments, traffic densities will be far higher, with vehicles much closer to each other, and to obstacles. The diversity of operations means the traffic management system must be able to cope with aircraft that have radically different characteristics sharing the same airspace.

Estimates show that the growth of commercial air traffic is already exceeding the capacity of a human-cantered system — and that is only for human piloted flights. The expected growth of unmanned and self-piloted operations will increase traffic by several orders of magnitude. To handle this dramatic growth, air traffic management must shift to a more scalable model: a digital system that can monitor and manage this increased activity (Airbus, 2019).

In operation, this implies UAV are no longer required to talk only to a particular entity, such as a designated ATC. Instead, UAV can communicate easily with their service providers of choice, who are held to relevant safety/security, and performance requirements by the aviation authorities and harmonize with the rest of the network to make optimal decisions based on specific flight objectives. Human ATC, meanwhile, will become airspace supervisors, dedicated on oversight, safety, and security.

4.1. Establishing new flight rules

Existing flight rules and airspace services limit or prevent drone flights. Drone traffic has a greater diversity of landing locations: not just airports, but vertiports and delivery platforms that could be on buildings, in backyards, and even on vehicles. These landing locations are spread throughout a region rather than concentrated at an airport— indeed, every home could be a potential landing site. The current system of approach and departure routes needs adapting for drones and helicopters. The in-flight phase can vary widely, too. Infrastructure inspection and emergency response can involve hovering near a ground location at a low altitude point. Agricultural missions involve low-altitude flights back and forth over a plot of land to measure soil or plant conditions. New kinds of missions require new kinds of traffic management.

The current air navigation system is largely organized around paths that travel between waypoints, increasingly defined ad-hoc in 3-D by satellites. Drone flights performing missions in lower density airspace could use free routing, with fixed routes, corridors, or other constructs to avoid conflicts, obstacles, or areas too dense for safe operation. In high-traffic areas like urban centres, airspace structure, infrastructure, and procedures may be required to enable safe operations. A delivery warehouse, for example, has many drones approaching and departing, requiring coordination to operate safely. Procedures can define a safe route through an otherwise sensitive space, such as crossing over an airport. Other procedures can organize safe routes between buildings in an urban core, with special navigation aids to ensure high-precision guidance in complex environments.

Aircraft today use Visual Flight Rules (VFR) or Instrument Flight Rules (IFR). These are essential for maintaining safe separation distances between aircraft to prevent collisions (Kovacik et al., 2019). Complying with these rules limits operations for drones and helicopters and does not allow for the introduction of new capabilities like automation in a safe and extensible way. Airbus (2019) indicated new flight rules to be established — for example, Basic Flight Rules (BFR) and Managed Flight Rules (MFR). BFR would cover flights that operate independently. They take full responsibility for their safety, routing, and separation from other air traffic. MFR will apply to flights that coordinate their trajectory with a traffic management service and follow its guidance to maintain separation. Traffic management services direct flights using MFR and monitor changes in the airspace, such as temporary restrictions or weather conditions. Flights receive control instructions to keep operations within acceptable risk tolerance thresholds. Real-time two-way communications report position and status so that traffic managers can coordinate with their aircraft. Around airports, ATM and UTM services work together. For example, they coordinate the direction of local traffic flows between fixed wing aircraft and unmanned drones at local airports based on weather conditions. Traffic management services provide basic information to pilots and autopilots about conditions in the airspace, regulation, and nearby traffic. Managed aircraft use this information as input for tactical self-separation and collision avoidance. The same general traffic information is useful to any pilot to improve their flight planning and in-flight situational awareness.

5. Conclusion

The main aim of this paper was to assess options and approaches to UAS integration and summarize by these means the knowledge of the process of gradual, safe integration of unmanned aerial systems into airspace. Based on the results of the analysis of the current state of the art and the adapting legal regulations, we have identified specific options, approaches and means of determining this process.

When analysing the data provided by senior field studies, conferences and scientific articles, we discovered that there is now a tremendous amount of effort to make UAS integration as fast and secure as possible. Research coupled with this paper also enabled the processing of specific strategies such as the creation of air corridors for drones of different categories and the possibility of applying these strategies. Based on these findings, it can be determined in which cases it will be best to apply the selected strategy or approach. In the case of the integration process, it is also necessary to follow this process in other, especially neighbouring countries, and to ensure the highest level of standardization and cooperation, which will significantly simplify international UAV flights in the future. We expect that in the decision-making process of introducing new regulations for UAVs. So, after that it will be possible to answer our question responsibly.

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THE ADVANTAGES OF PLANT PROTECTION BY USING UAV OF AIRCRAFT CONFIGURATION AND ULV TECHNOLOGY

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Abstract

The article deals with the design of agricultural UAVs. In recent years, various agricultural UAVs (mainly the copter configuration) have been developed for processing small fields using the method of ultra-low-volume spraying. The proposed project of an agricultural UAV aircraft configuration has several advantages especially when used on large fields. Due to the high flight speed, high payload and the duration of flight time without refuelling, this aircraft has a fairly high performance in the process of protecting plants from diseases and pests. In addition, a relatively simple infrastructure, based on the years of experience in the use of manned aircraft in agriculture, allows, by analogy, to develop an unmanned aviation system for agricultural purposes. Flights are currently underway to test UAV control systems when manoeuvring at low altitudes near obstacles.

Keywords

UAV, agricultural UAV, ultra-low volume (ULV), aircraft, copter, airplane configuration

1. Introduction

According to the revised data from FAO, UN WFP, UNICEF and WHO, the number of hungry people in the world is growing, reaching 821 million in 2017. This means that every ninth person on the planet has been affected by hunger, according to the report published in "The State of Food Security and Nutrition in the World - 2018 " (FAO, 2018). The world is moving towards a long period of conflict related to increasing food prices and an acute shortage of food. Hunger is no less dangerous than terrorism, because, together with poverty, it creates a threat to world security.

One of the ways out of this situation is the so-called "Second Green Revolution", based on the introduction of new technologies (Schröder, 1998 & Carvalho et al., 2011). This article discusses the private aspect of choosing effective plant protection technologies based on the latest advances in mechatronics and aeronautics - agricultural unmanned aerial vehicles (UAVs).

2. Prospective technologies in the agricultural sector

What are the ways to increase the yield of the field? As can be seen in Fig. 1 a large role in this agro-technological cycle to achieve the ultimate goal is assigned to plant protection. The introduction of appropriate plant protection products would raise field yield by up to 50%. Currently, these are ground transportation, manned aircraft and UAVs. In the same sequence, we consider the comparative levels of each of these assets development, their advantages and disadvantages, as well as the immediate prospects for their implementation in the agricultural sector.

Figure 1: Agro-technological production cycle. Source: Authors.

3. Level of development

3.1. Ground transportation

There are countries where, for reasons of environmental safety and the concept of precision farming, even today only ground equipment is used to protect plants or, in some cases, in combination with agricultural aviation. Ground-based equipment, of course, has its advantages over aircraft (LA), which (especially airplanes) are limited to navigation and environmental requirements. Nevertheless, by a large number of criteria, ground transportation is inferior to aviation, although recently there has been a trend towards automation of managerial functions for existing tractors, for example, Magnum, JohnDeer (CaseIH and CNHIndustrial's Innovation Group, 2016 & Yun et al., 2018) and others. Recently, CaseIH (USA) specialists have created a completely new type of tractor (Fig. 2) on autopilot and have high hopes for it (Schröder, 1998). The car was equipped with a variety of sensors that help navigate in space. The "brain" of the tractor analyzes the signals coming from both the sensors and the person, if necessary, and signals the operator about emergency situations. The unmanned tractor is controlled by means of a tablet or computer. Indeed, using the software of the devise allows operating it fully autonomously.

Soon, unmanned tractors, apparently, will make a real competition to manned agricultural aviation.

Figure 2: Unmanned tractor company of CaseIH. Source: (CaseIH and CNH Industrial's Innovation Group, 2016).

3.2. Piloted aircraft

Manned agricultural aircraft have a long history. Thus, the An-2 aircraft designed at O. Antonov Design Bureau in 1947 has continued performing a large amount of work in agriculture in many countries worldwide. Fig. 3 shows Russia's new recently manned agricultural aircraft Su-38L. This fact proves that it is still too early to write off manned agricultural aircraft, especially where there are trained personnel, infrastructure and deep-rooted traditions of using manned aircraft in agriculture.

Figure 3: Manned aircraft of Sukhoi company. Source: (Sukhoi, 2017).

3.3. Unmanned Aerial Vehicles

Why did the agricultural UAVs of copter and aircraft configurations appear, even in a compromise hybrid design? The unmanned helicopter can be considered as a kind of copter that deserves a separate study and publication. In this article we will conduct a comparative analysis of two UAVs configuration: copter and aircraft. UAVs have a long list of advantages compared with manned aircraft:

- The main advantage of the UAV is a significantly lower cost of their creation and operation, provided that the tasks performed are equally effective;
- Fuel economy when using internal combustion engines;
- Low weight allowing the use of electric motors;
- Due to the weight of the pilot and his/her workplace, it is possible to increase the payload, that is, to place on board more working material or fuel;
- Significant reduction in take-off and landing space;
- High operational efficiency;
- Improved field processing performance;
- Lack of pilots reduces the risk of personnel and financial losses for training;
- No problem with pilot fatigue;
- A UAV can operate at night when there is less wind, less demolition of the working material.

In addition to purely technical advantages, it is worth noting the main economic benefits of UAV application for plant protection:

- 60-percent reduction in plant protection operating costs;
- 30-percent yield increase in the farms which have not been previously engaged in plant protection;
- 3-fold increase in field processing performance;
- 5-fold reduction in fuel consumption.
- However, it is necessary to recognize the fact that the UAV of the aircraft configuration is not without many serious drawbacks as compared with helicopters:
- The need for a runway;
- Difficulties in accurate processing around the perimeter of the field can lead to the violation of environmental legislation – the need to introduce sanitary buffer zones along the field borders;
- Limited field processing with difficult mountainous terrain.

3.3.1. <u>Copters</u>

In the last decade, a large number of copters (quadcopters, octocopters, multicopter), developed even far in non-aviation countries, have appeared. Their developers offer them as an inexpensive and easy-to-use plant protection product similar in design and flight-technical and commercial characteristics to copters (Kabra et al., 2017 & Yun et al., 2014 & Hunt et al., 2018).

Fig. 4 shows a typical sample of an agricultural UAV Copter vehicle (DJI Agros MG-1, 2017). This Chinese DJI Agros MG-1 drone sprayer is designed for field protection with a predominantly flat terrain. As seen from above, the device is of a star-shaped structure with a block of equipment in the center (battery, navigation equipment with GPS radio transmitter), as well as a removable plastic tank for working chemical solutions attached by strips.

On each "beam" of this star there is a propeller with a drive from an electric motor and a nozzle for spraying the working fluid. The device is controlled from a telephone or mobile computer, it starts vertically from the ground. You can control the flight manually or automatically, denoting the starting and landing points on the computer screen, as well as the trajectory and speed. The device is controlled from the keyboard of a mobile computer. The time spent in the air is up to 24 minutes, the maximum speed of 79 km / h within a radius is of up to 5 km from the operator.

The proposed design has several advantages:

- stability in static modes (hovering), which facilitates control and turns in out;
- a significant reduction in construction costs and weight due to the absence of the fuselage;
- an increase in power supply due to the use of an electric drive instead of an internal combustion engine, which has lower efficiency, and the absence of converters of mechanical moments.

Figure 4: Agricultural UAV of copter configuration. Source: (DJI Agros MG-1, 2017).

As a rule, the main parameters of modern agricultural copters are in a narrow range of values: flight time over the field within 20-30 minutes, and payload weight of 10-20 kg. The bottleneck of the copters is the power sources of electric motors, on-board equipment and avionics. The capacity of a modern battery limits a copter flight time before replacing or recharging it with 40-50 minutes. Therefore, these parameters effect the economic efficiency of copter performance (Kedariet et al., 2016 & Rendl et al., 2014). To reduce the specific energy consumption and improve aerodynamic parameters, some UAV developers chose the path of motorists, that is, create a hybrid vehicle, combining the advantages of aircraft and copter in its design.

3.3.2. Multirotor quadcopter

In Ukraine, the company has chosen this path (Kray Technologies 2017). Its brainchild Kray is a hybrid of a copter and an aircraft (Fig.5). Eight propellers provide a vertical take-off, and traction propeller and wing provide flight at the speed of up to 110 km/h at a vista of 1 m above the plant, considering the relief and obstacles. Productivity is 300-500 hectares of land per day.

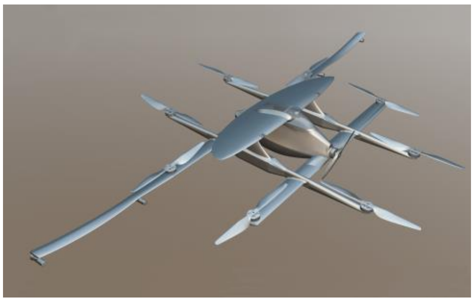

Figure 5: Multirotor Quadcopter Kray. Source: (Kray Technoilogies, 2017).

The prototype design includes two folding rods and 5-meter-disperse sprayers. In addition, it is equipped with the terrain recognition system and rotary atomizers which ensure the accurate introduction of concentrated protective equipment, while the rotor will fly over the field of 1 meter in height. The copter operates on promising concentrated products using ULV technology, as well as well as for making leaf fertilizers or chemicals in the fields.

The Ukrainian Kray drone has several competitors on the market, including the above DJI Agros MG-1. The latter has already appeared on sale in online stores. It is more compact in size, simple in programming tasks, and the price cheaper by almost three times - $ 15,000 but is not capable of developing such a high speed as it is equipped with the tank that is half as large in volume.

3.3.3. UAV of Aircraft Configuration

Against the background of numerous varieties and sometimes simply exotic copter designs, the aircraft UAV configurations may seem rather conservative (Yun et al., 2017 & Pederiy et al., 2015 & Giles et al., 2015). However, in plant protection technologies, there are situations when the aircraft configuration is clearly superior to the engine one. Firstly, there are countries, such as Ukraine, Kazakhstan, the USA, Canada, Australia and others, where the fields have even relief and without obstacles in the form of power lines, buildings, structures, antennas, etc. In this case, the aircraft can handle large areas per flight. To do this, it must have a large tank for both fuel and working material, as well as high speed on the rut. Secondly, as seen on Table 1, some chemicals, especially fertilizers, are applied to the soil with a high consumption rate, which again places high demands on aircraft performance and tank capacity.

Table 1. Consumption rates of plant protection products. Source: Authors.

Chemicals	Herbicides	Fungicides	Insecticides and Acaricides	Regulators Growth	Liquid Fertilizer “ Aydar”	Ammonium Nitrate	Ureaa
Norm, l/ha, kg/ha	0.08-6.0	0.2- 2.5	0.1-3.0	2.0-3.0	6.0-9.0	150-250	100-200

Given the above, a group of Aero Drone company's employees under the direction of Y. Pederiy designed, manufactured and got ready for mass production of DR-60 UAVs of the aircraft configuration. Below is a brief description of this UAV.

Purpose

The DR-60 UAV is one of the largest UAVs in Ukraine today, specifically designed for use in the agricultural field to protect plants by spraying fields with a payload capacity of up to 60 kg, which allows for manual flight within the visibility zone under operator's control. The UAV development was carried out according to civil standards for the development of aircraft. The DR-60 allows ULVT fields to be processed at an application rate in the range of 1 to 3 litres per hectare. While spraying it uses standard rotating nozzles (similar to Micronair) with a droplet size of at least 100 micrometres and a flow rate of up to 1 litre per minute. Sprays, chemical tanks and pumping equipment are not included in the DR-60 UAV configuration.

UAV components:

- Technological panel for UAV pre-flight inspection and control
- UAV battery charger
- A set of spare parts and accessories for minor repairs in the field
- Operation manual.

General view of the UAV

Fig. 6 shows a general view of the DR-60 UAV, which is an aircraft LA with an overhead wing, pulling propeller and an internal combustion engine. UAV is equipped with the main chassis on the front spring and a rear wheel. Onboard equipment is powered by two high-capacity lithium-ion batteries and an onboard generator. The wing, fuselage and engine of the UAV are made of metal, which significantly increases the aircraft strength, and also provides its maintenance and repair.

Figure 6: UAV general view

1 – aileron, 2 – horizontal tail, 3– fin, 4 –rudder, 5– wing, 6 – fuselage (with equipment), 7– chassis, 8– engine,9 – propeller, 10 – chemical tanks, 11 – rotating nozzles

The on-board equipment consists of that for aircraft monitoring and control (OCULA), electrical equipment (ET) and replaceable attachments (HO) for carrying out plant protection works. ET includes a set of Li-Ion batteries, 9V (2 pcs.) for powering all OKULA and Li-Po 7.5V, 4A batteries for powering FUTABA BLS 175, HITEC HSB-9380TH servo drives.

OKULA has a Taranis X9D receiver for receiving signals from a ground transmitter that is controlled by a ground operator. The control signals are transmitted to the receiver through a channel at a frequency of 2.4 GHz, using FASST technology. OKULA provides in manual mode:

- UAV take-off and landing
- Flying within sight
- Switching on / off pumps that supply liquid to rotating nozzles

Remote control FUTABA 14MZ

The control panel TARANIS of the X9D brand, the standard remote-control model of radio models, is designed to control the UAV. The rules for operating the remote control are described in the "Operation Manual" of this product. The control of the UAV remote control is carried out in manual mode. The console is not equipped with a receiver of video signals and is intended only to control the UAV within sight of the operator. The control panel is designed to perform the following functions:

- Flap control
- Aileron control
- Gas damper control
- Steering wheel height
- Steering rudder
- Brake control

An additional purpose of the technological panel is to check the condition of the electromechanical control devices of the UAV, as well as to check the condition of the power plant.

Charger

The charger is used to charge the batteries. Rules for working with a charger and charging batteries are described in the "Charger Handbook".

Technical specifications

The main flight characteristics of the UAV are given in Table 2.

Table 2: Technical specifications. Source: Authors.

Maximum airspeed	100 km/h
Cruising flight speed	80 km/h
Flap speed without flaps	50 km/h
Landing speed	65 km/h
Maximum flight altitude	3 km
Maximum flight time (depends on weather conditions)	1.5 h
The working range of the radio control UAV	3 km

Control range	In the line of sight, up to 1 km
Engine type Hirth F33	Two-stroke ICE
Maximum payload weight	60 kg
Maximum take-off weight	150 kg
Length	4 m
Wingspan	6.5 m
Aerodynamic quality	10
Operating temperature range	-20… +450 C

Preparation of the UAV to work

The first stage - determining the place of take-off and landing - includes the study of the terrain at the proposed starting point. It is desirable to consider:

- the starting point should be chosen as high as possible relative to the intended route with the minimum distance from the fields in order to increase the useful time and to achieve maximum results;
- it is preferable to choose a launch pad with a low grass cover. The size of the site must be at least 150x20 m provided that there are no objects in the surrounding area that would prevent the normal mode of take-off, landing and the search for UAVs (rivers, lakes, ravines, buildings, masts, towers, etc.) within a radius of 400 m.

At the first stage it is also necessary to:

- determine the position of the cardinal points.
- determine the direction and speed of the wind (the direction and speed of the wind at the surface of the earth and at the working height may differ).
- determine the direction of the route relative to the take-off point and make sure that there are no obstacles in this direction to ensure direct visibility.
- determine the direction of the launch and make sure there are no obstacles in this direction.
- ensure that there are no obstacles in the landing zone.

It should be noted that the landing machine comes against the wind. For a safe launch and landing of a UAV, there must be no obstacles: buildings, masts, towers, factory pipes with a height of more than 50 meters.

The landing site is selected near the starting point from the consideration of the possibility of UAV operator's visual inspection by approach and landing. To land a UAV, a flat terrain with a size of 150x50 m is selected. There should be no objects on the ground that could be damaged by landing UAV, namely bushes and trees, stumps and stones, poles and power lines, buildings and structures, water bodies. When landing in manual mode, the landing point is determined by the operator based on current weather conditions, size, location and features of the landing site. To carry out inspections of specific objects, the flyby mode of a given object with a given flyby radius is used (Fig. 7). This mode is widely applicable when object coordinates are known, and its state needs to be clarified.

The second stage is flight preparation, which includes setting up the operator's workplace, namely: turning on the on-power toggle switch of the servo drives; turning on the UAV manual control transmitter; check the installation of communication transmitter with an onboard receiver, rejecting the control knobs on the transmitter and tracking the development of control rudders on the UAV. Now the UAV is on and ready to go.

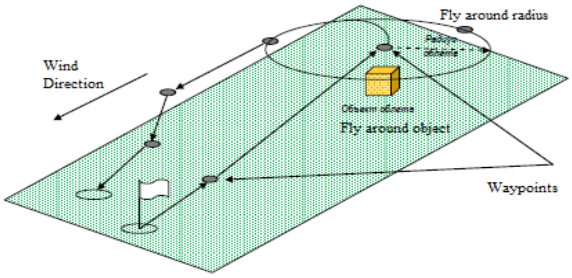

Figure 7: Circling a given object. Source: Authors.

4. Conclusion

In world practice, thousands of different types of aircraft are used annually to protect plants, with the help of which millions of hectares of agricultural and forest lands are treated with chemical and biological preparations. According to large analytical companies (PWC, Goldman Sachs, Markets and Markets, IDTech Exlheubt, 2017), the agricultural sector will be the largest in terms of civilian use of drones by the size of the segments in the next 5 years and the potential size of the agricultural market will increase from $ 32.4 billion up more than $ 150 billion.

Despite the high efficiency, the main economic benefits from the use of UAVs for plant protection in comparison with terrestrial methods of protection are: increase in yield by 30% in the farms which have not been previously engaged in plant protection; 60-percent reduction in plant protection operating costs; 4-fold increase in field processing performance; 5-fold reduction in fuel consumption compared with manned aircraft.

ULV technology, the need to make chemicals with a high rate of consumption is not removed from the agenda. Therefore, at present, in Ukraine, at the National Aviation University, the assembly of a prototype agricultural UAV of an aircraft circuit with a 300-liter tank capacity is already being designed and is being completed. It is obvious that in the near future unmanned agricultural aircraft with a carrying capacity of the An-2 aircraft, that is 1500 kg, will appear.

If we compare the UAV of vertical take-off and landing (copters and unmanned helicopters) with the UAV of an aircraft circuit, then, undoubtedly, the latter lose by take-off and landing parameters. For example, the DR-60 UAV requires a 150x20 m platform. Although in countries where previously piloted agricultural aircraft were used or are used, it is possible to organize the operation of an UAV aircraft configuration. In Ukraine and the countries of the former USSR, a sufficiently developed network of such airfields remained.

The authors of the article do not consider Copter and aircraft agricultural UAVs only as competing NLA. It is more profitable to consider them as complementary, using the advantages of each configuration (Marintseva et al., 2019). In small areas, especially in mountainous areas with a complex perimeter geometry, it is more expedient to use helicopter or cruiser

UAVs, and on large fields with a flat profile - airplane UAVs. But even large fields are not always a rectangle without any obstacles that it is almost impossible to accurately fly around an aircraft UAV. This job of cleaning up small “patches” will be better done by a copter or ground vehicle.

Another direction of the rapid development of the fleet of agricultural UAVs is the conversion (Belan et al., 2018 & Marintseva, 2014) of existing manned general-purpose aircraft into agricultural ones. Here you can win not only in the rate of fleet growth, but also in cost savings.

Obviously, any aircraft, including unmanned, originally designed to solve specific problems, will be functionally more efficient than a modernized, re-equipped manned aircraft or a helicopter. But we must not forget that with a successful choice of a manned prototype, an unmanned transformation may be preferable to the originally developed version, which meets all technical and economic requirements of the customer. This approach to creating a new UAV has several advantages, such as cost savings in the design, production and testing phases; availability and logistics of spare parts; the possibility of using the existing service base; shortening the project development time frame and launching the mass production of UAVs. The term "conversion" refers to the process of converting light and ultralight manned aircraft into unmanned aerial vehicles for their subsequent economically and technically efficient use in various sectors of the economy. The effectiveness of such a UAV will largely depend on how well the above-mentioned transformation will be performed. To solve the conversion problem, we need the appropriate theoretical foundations, a certain set of algorithmic and software tools, as well as technical tools that provide the full cycle of testing UAV control systems in all flight modes.

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COMPETITIVE CHALLENGES FACING THE AIR NAVIGATION SERVICES IN EUROPE

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Abstract

European aviation is facing new competitive challenges in a rapidly evolving global market, in particular as a result of a shift of economic growth to the East. These new competitors are benefitting from the rapid economic growth of the entire region, notably Asia, and from aviation becoming a strategic element in their home-country's economic development policies. With an annual growth forecast of 6%, scheduled passenger traffic in the Asia Pacific, the region is likely to grow faster than other regions until 2034 when it will account for 40% of world air traffic. China is expected to become the world's largest air transport market, overtaking the United States of America in 2023 in terms of number of passengers carried (Sloveniacontrol, 2018).For the EU aviation industry to remain competitive, it is essential that market access is based on a regulatory framework which promotes EU values and standards, enables reciprocal opportunities and prevents distortion of competition. The main challenge for the growth of European aviation is to reduce the capacity and efficiency constraints, which are seriously impeding the European aviation sector's ability to grow sustainably, compete internationally, and which are causing congestion and delays and raising costs. This paper examines competitive environment and performance of seven European Air Navigation Services Providers (ANSP) of Austria, Bosnia and Herzegovina, Croatia, Czech Republic, Hungary, Slovak Republic and Slovenia from European Commission´s target perspective.

Keywords

Air Navigation Services Providers, Functional Airspace Blocks, Performance Review Committee

1. Introduction

Airports together with air traffic management services providers constitute the key elements of the infrastructure of civil aviation. The quality, efficiency and cost of these services have become increasingly important to the competitiveness of the industry (Materna, 2019). In Europe, airports and air traffic management can safely handle up to 33,000 flights per day. Yet, European airspace as a whole is inefficiently managed and unnecessarily fragmented, and a slow implementation of the Single European Sky framework means higher costs for the airlines, which directly affects their competitiveness. The estimated costs of the EU's fragmented airspace represent at least €5 billion a year. Such an inefficient use of the airspace causes higher prices and delays for passengers, increasing fuel burn and CO2 emissions for operators, and impedes the efforts to improve environmental performance. In addition, major European airports are predicted to face a capacity crunch in the near future.

The Single European Sky is a concrete example of where the EU can make a difference by raising capacity, improving safety and cutting costs while minimising aviation's environmental footprint. This was the initial ambition more than a decade ago, but the project is still not delivering. Despite some achievements towards a better performing network, the level of cooperation between Member States air navigation service providers is still far from optimal, and the technology used is not harmonised or state-of-the-art. EU Member States must overcome these challenges in order to achieve a true Single European Sky, which is one of the most fundamental challenges affecting the performance and competitiveness of the EU's aviation system today. For example, a fully optimised air traffic management system would reduce the costs stemming from inefficiencies (delays, and longer routes etc.).

As an important step in unleashing this potential for the EU aviation sector, the Commission urges the Council and European Parliament to adopt the Single European Sky (SES2+) proposals, in order to ensure the effectiveness of functional airspace blocks (FAB) and network functions and the swift implementation of the EU-wide targets for the performance scheme based on a fully independent performance review body.

The efficient governance of the Single European Sky (SES)remains a priority for the Commission. The respective tasks of the European Aviation Safety Agency and Eurocontrol should be defined in a manner that ensures that both organisations complement each other's tasks, so that overlaps can be avoided, and costs reduced.

In this context, it is important to deploy technological solutions in a timely and coordinated manner. A number of instruments have been developed to this end, such as the air traffic management Master Plan, Common Projects and the Deployment Programme. They are implemented by public-private partnerships, notably the SESAR Joint Undertaking for the definition and development activities and the SESAR deployment framework partnership for deployment. Both development and deployment activities require appropriate financial support. So far, the EU is contributing through programmes such as Horizon 2020 and the Connecting Europe Facility.

2. Data Envelopment Analysis (DEA) of Functional Airspace Block Central Europe (FAB CE)

European Commission has very detailed legislation how to measure and how to improve performance of Air Navigation Service Providers. Every ANSP has a trackable record as an individual provider and as a member of respective FAB as well. On yearly basis, Performance Review Committee evaluates, how single ANSPs contribute to European, regional (Functional Airspace Block's) and state targets.

The ultimate goals of the technological modernisation of air traffic management through the deployment of the Single European Sky Air traffic management Research project (SESAR) are to enable a reduction of air traffic management costs, greater level of safety, increased operational efficiency for airspace users by reducing delays, fuel burn and flight time, an increase in capacity and a reduction of CO2 emissions. All these elements will increase the environmental benefits of SESAR solutions and are fully linked to the overall air traffic management performance scheme.

Focusing on FAB CE this section compares performance of ANSPs of seven members (Austria, Bosnia and Herzegovina, Croatia, Czech Republic, Hungary, Slovak Republic and Slovenia) from European Commission target perspective.

2.1. Data Envelopment Analysis

Data Envelopment Analysis (DEA) theory was created in the 1970s. It was built on the idea of Farrell's 1957 "Measuring efficiency of decision-making units." The basic task of the DEA models is comparing organizational units within a group. It is a method based on the use of linear programming that was originally developed to measure the effectiveness of non-profit organizations such as schools, hospitals, state and government. This is the reason why this model is the most suitable for assessing the performance of the Air Navigation Providers. These are considered as public service non-profit organizations. It must be stressed out that ANSPs generate certain profit accepted by European Commission.

DEA is a relatively new non-parametric approach for evaluating the performance of a set of peer entities called Decision Making Units (DMUs, individual ANSPs in our case) which convert multiple inputs into multiple outputs. The characterization of the unit of assessment as “decision making” implies that it has control over the process it employs to convert its resources into outcomes.

Data Envelopment Analysis is a method for measuring comparative or relative efficiency. We speak of relative efficiency because its measurement by DEA is with reference to some set of units, we are comparing with each other. The efficiency score is usually expressed as either a number between 0-1 or 0-100%. A DMU with a score less than 100% is deemed inefficient relative to other units.

Since DEA was first introduced in 1978, researches in a number of fields have in a short period of time recognized that DEA is an excellent and easily used methodology for modelling operational processes for performance evaluations.

2.1.1. Advantages of DEA model

DEA is a framework analysis which accommodates a comprehensive view of organisational performance. It is an appropriate tool for assessing performances of an organisation or firm. This is partially due to the fact that a multitude of subjective factors affect the quality and productivity of a service that needs to be well managed. Listed, we can find main advantages of DEA model:

- Each DMU can be characterized individually.
- Inefficient DMUs are improved by projecting them on the efficient frontier (envelopment).
- It facilitates making inferences for each DMU among the inferences on the DMUs’ general profile.
- Multiple-output and multiple-input can be handled in various DMUs measurements.
- A focus on a best-practice frontier, instead of on central-tendencies, i.e. every DMU is compared to an efficient unit or a combination of efficient units. The comparison, therefore, leads to sources of inefficiency of DMUs that do not belong to the frontier.
- No restrictions are imposed on the functional form relating inputs to outputs.

2.1.2. Disadvantages of DEA model

- As DEA is an extreme point technique, it is very sensitive to noise (even for symmetrical noise with a zero mean) that may cause significant errors in efficiency measurements.
- Statistical hypothesis tests are difficult because DEA is a non-parametric.
- The standard formulation of DEA is based on separate linear programmes for each DMU, which is computationally demanding.
- Difficulties in aggregating different aspects of efficiency especially whenever DMUs perform multiple activities.
- Insensitivity to intangible and categorical components (e.g. service quality in a bank branches).
- There are crucial problems related to mixing multiple dimensions in the analyses. For instance, consider a DMU performing two different activities; the DMU could be found efficient in the first activity but inefficient in the second. For example, a bank’s branches are a single platform that management uses to sell financial services to customers as well as providing more traditional banking services such as processing deposits or loan. Furthermore, it is difficult to simultaneously assess the sales efficiency and the service efficiency of the branch. Because the relevant inputs and outputs for individual activities are not directly comparable, the analyst would have to run two DEA models one for sales and the other for services. DEA is intended for estimating the relative efficiency of a DMU

but not specifically addressing absolute efficiency. In other words, it measures how well the

- It is impossible to rank efficient units absolutely because all DMUs located on the frontier surface have 100% efficient score.
- From managerial point of view, it may be more useful to compare DMUs to a frontier of absolute best performance. So, the analyst would be able to better detect, for example, a DMUs network's true inefficiency. In fact, one might argue that efficient units may not be efficient enough, so the created frontier does not reflect the real potential of the DMU network.
- There is no specifically robust methodology for evaluating or testing the appropriateness of a set of factors in an efficiency study. A DEA model can indicate how efficient a specific DMU is out of a given set of factors, and what its efficiency score is. It does not indicate, however, whether the chosen factors can provide the right efficiency.

2.2. Results – performance of individual ANSPs in Key Performance Areas

2.2.1. Safety and security

Safety and security are pre-requisites for a competitive aviation sector. With the aviation traffic in Europe predicted to reach 14.4 million flights in 2035 (European Commission, 2016). This will allow the EU aviation sector to continue to develop safely in the future. To this end, the regulatory system has to be better equipped to identify and mitigate safety risks, in a quicker and more effective manner. This can be achieved by introducing a risk and performance-based approach to safety regulation and oversight, by closing existing safety gaps and by integrating other technical areas of regulation connected to safety more deeply, such as aviation security.

Efficiency and safety gains can be achieved through a better use of available resources at EU and Member States level. To this end, a framework for the pooling and sharing of technical resources between the national authorities and the European Aviation Safety Agency should be put in place. It should allow Member States to transfer on a voluntary basis, responsibilities for the implementation of European Union legislation, to the European Aviation Safety Agency or to another Member State. Regulatory responsibility would become clearer and duplication would be avoided. A single European aviation authority should be the longer-term ambition.

In this particular case we will not take into account the safety as a parameter needed for a new efficient model of provision of air navigation services. Base on the PRB Annual Monitoring Report 2017 safety level has already been achieved on national and FAB CE level.

2.2.2. Capacity

The EC Decision 2015/347 published on the 2nd March 2015 states that: "The performance targets in the key performance area of capacity submitted by the Czech Republic, Croatia, Hungary, Austria, Slovenia and Slovakia as regards FABCE should be revised downwards. As a minimum, those targets should be in accordance with the respective FAB reference values set out in the Network Operations Plan. Where the Network Operations Plan specifies remediation or mitigation measures, account should be taken of those measures when revising the performance targets." (Performance Review Board, 2015)

Table 1: Individual ANSP contributions to the FAB reference value of En-route delay level (in minutes per flight). Source: (Performance Review Board, 2015).

Year		2015	2016	2017	2018	2019
FAB reference value		0.30	0.29	0.29	0.29	0.29
Revised FAB target		0.29	0.29	0.28	0.28	0.27
ANSP contribution	Austro Control	*0.21*	*0.21*	*0.20*	*0.19*	*0.19*
	Croatia Control	*0.23*	*0.22*	*0.21*	*0.21*	*0.19*
	ANS CR	*0.09*	*0.1*	*0.09*	*0.10*	*0.10*
	HungaroControl	*0.06*	*0.05*	*0.05*	*0.04*	*0.05*
	LPS SR	*0.10*	*0.10*	*0.10*	*0.11*	*0.10*
	Slovenia Control	*0.21*	*0.21*	*0.22*	*0.23*	*0.22*
Aggregated ANSP contribution		***0.31***	***0.30***	***0.29***	***0.29***	***0.28***

2.2.3. Cost-Efficiency

Concerning the key performance area of cost-efficiency, the targets expressed in en-route determined unit costs submitted by Member States have been assessed, in accordance with the principles, in conjunction with point 1, of Annex IV to the Implementing Regulation (EU) No 390/2013, by taking account of the trend of en-route determined unit costs over the second reference period and the combined period of the first and the second reference period (2012-19), the number of service units and the level of en-route determined unit costs in comparison to Member States having a similar operational and economic environment.

Now we have initial input and output parameters for DEA methodology – determined costs, delays and service unit cost. The section shows the data of LPS SR only. The more data we provide the more to the DEA methodology the more complex picture we can get. From this perspective we added more parameters to the calculation - number of movements, size of particular FIR, number of employees and costs of Gate-to-Gate approach. As a reference base line, we took data from ANPS's Annual Reports 2018.

Table 2: Slovakia - revised en-route cost-efficiency targets for Reference Period 2. Source: (Letové prevádzkové služby SR, š.p., 2018).

Revised performance plan	**2015**	**2016**	**2017**
Determined cost (mil. EUR)	59,3	61,9	63,0
Service Units (in thousands)	1078	1126	1186
Determined unit cost (EUR)	54,99	52,54	52,61

2.2.4. Environment

The future competitiveness of the European air transport sector and its environmental sustainability go hand-in-hand. Regular and more holistic monitoring and reporting on the environmental impacts and progress on the implementation of the different policies and initiatives across the EU air transport system will help inform about the sector's impacts on the environment and provide a valuable contribution to further decision-making. High environmental standards have to be preserved and enhanced over time in order to ensure that aviation develops in a sustainable manner, avoiding or minimising harmful effects on ecosystems and citizens.

As regards emissions from aviation, the EU has put in place powerful regulatory tools such as the Emission Trading Scheme (EU ETS) addressing greenhouse gas emissions, including from aviation.

The International Civil Aviation Organization (ICAO) plays a critical role in the development of a global solution to address greenhouse gas emissions from international aviation. The EU, through its Member States acting within the framework of ICAO, pursues a robust Global Market Based Mechanism to achieve carbon neutral growth from 2020 to be reviewed over time as appropriate, and to be made operational from 2020, as well as the adoption of a first CO_2 standard for aircraft. At the ICAO Assembly in 2016, Europe should reach out to other regions of the world to achieve a truly global mechanism.

For the purpose of this paper we will not calculate with the CO_2 emission saving mechanism contribution. Obviously, if we design efficient model in provision of air navigation service, we achieve significant CO_2 savings.

3. DEA model outcomes

The Delay is one of the most important targets set by European Commission used for assessing performance of Air Navigation Service Providers. We set the delay as output parameter while Number of Movement, Number of Employees, Determined Cost and Size of FIR represents the input. First, we compared just 2 parameters in every FAB CE Member State (ANSP) to figure out, what ANSP is the most efficient under the current legislation.

This section shows the comparison of Determined Costs vs. Number of Movements.

Table 3: Determined costs vs Number of Movements Source: Authors.

DMU	A	SK	CRO	CZ	HU	SLO
NoM (mil.)	1,23	0,52	0,58	0,85	0,84	0,39
Cost (mil. EUR)	195,9	63	90,1	148,1	84,7	35,4
Cost/NoM	158,50	120,61	155,11	173,55	101,04	91,73
Efficiency (%)	57,88	76,06	59,14	52,86	90,79	100

Table 4: Inputs to the DEA model Source: Authors.

	Inputs			
Country/ANPS	NoM	NoE	FIR (km²)	Cost
A Austrocontrol	1235994	1003	83879	195900000
SVK LPS SR	522353	485	49035	63000
CRO Crocontrol	580892	740	129000	90100000
CZ ANS CR	853364	989	78865	148100000
HU Hungarocontrol	838279	743	93030	84700000
SLO Sloveniacontrol	385897	230	20273	35400

Table 5: Outputs of the DEA model. Source: Authors.

	Outputs		
Country/ANPS	Delay	DUC	Weight
A Austrocontrol	0,29	71,35	0
SVK LPS SR	0,04	52,61	0
CRO Crocontrol	0,12	46,53	0
CZ ANS CR	0,05	42,1	1
HU Hungarocontrol	0,01	34,69	0
SLO Sloveniacontrol	1,17	61,71	0

4. Conclusions - complex ATM solution

Today's business world is of growing economy and globalization, so most of the companies are struggling to achieve the optimal market share possible on both market level i.e. Domestic and International market. Day by day businessperson works to achieve a most well-known goal i.e. "being the best by what you perform as well as getting there as quickly as possible". So firms work effortlessly to beat their rivals they assume various ways to try and do thus. Some of their ways might embody competitive within the market of their core competency. Therefore, it is ensuring that they need the best knowledge and skills to possess a fighting likelihood against their rivals in that business.

Every business wants the optimum market share (growth) over their competitors, so companies are trying to get optimum growth by using the most common shortcut i.e. Merger and Acquisition. The growth main motive is financial stability of a business and also the shareholders' wealth maximization and main coalition's personal motivations. Mergers and acquisitions provide a business with a potentially bigger market share and it opens the business up to a more diversified market. In these days it is the most commonly use methods for the growth of companies. Merger and Acquisition basically makes a business bigger, increase its production and gives it more financial strength to become stronger against their competitor on the same market. Mergers and acquisitions have obtained quality throughout the world within the current economic conditions attributable to globalization, advancements of new technology and augmented competitive business world.

The main idea behind mergers and acquisition is one plus one makes three. The two companies together are more worth full than two classified companies at least that's the concluding behind mergers. Merger is the combination of two or more firms, generally by offering the shareholders of one firm's securities in the acquiring firm in exchange for the acquiescence of their shares. Merger is the union of two or more firms in making of a new body or creation of a holding company (European Central Bank, 2017).

It involves the mutual resolution of two firms to merge and become one entity and it may be seen as a choice created by two "equals". The mutual business through structural and operational benefits secured by the merger will reduce cost and increase the profits, boosting stockholder values for each group of shareholders. In other words, it involves two or more comparatively equal firms, which merge to become one official entity with the goal of making that's value over the sum of its components. During the merger of two firms, the stockholders sometimes have their shares within the previous company changed for an equal number of shares within the integrated entity. The fundamental principle behind getting an organization is to form shareholders' wealth over and higher than that of two firm's wealth.

The advantage and disadvantages of merger and acquisition are depending of the new company's short term and long-term strategies and efforts. That is because of the factors likes market environment, variations in business culture, acquirement costs and changes to financial power surrounding the business captured. So, following are some advantages and disadvantages of merger and acquisition are:

4.1. Mergers and acquisitions - advantages

- The most common reason for firms to enter into merger and acquisition is to merge their power and control over the markets.
- Another advantage is Synergy that is the magic power that allow for increased value efficiencies of the new entity and it takes the shape of returns enrichment and cost savings.
- Economies of scale is formed by sharing the resources and services. Union of 2 firm's leads in overall cost reduction giving a competitive advantage, that is feasible as a result of raised buying power and longer production runs.
- Decrease of risk using innovative techniques of managing financial risk.
- To become competitive, firms have to be compelled to be peak of technological developments and their dealing applications. By M&A of a small business with unique technologies, a large company will retain or grow a competitive edge.
- The biggest advantage is tax benefits. Financial advantages might instigate mergers and corporations will fully build use of tax- shields, increase monetary leverage and utilize alternative tax benefits.

4.2. Mergers and acquisitions - disadvantages

- As a result of M&A, employees of the small merging firm may require exhaustive re-skilling.
- Company will face major difficulties thanks to frictions and internal competition that may occur among the staff of the united companies. There is conjointly risk of getting surplus employees in some departments.
- Merging two firms that are doing similar activities may mean duplication and over capability within the company that may need retrenchments.
- Increase in costs might result if the right management of modification and also the implementation of the merger and acquisition dealing are delayed.
- The uncertainty with respect to the approval of the merger by proper assurances.
- In many events, the return of the share of the company that caused buyouts of other company was less than the return of the sector as a whole (Richard, 2009).

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COLD FRONT AND ITS INFLUENCE ON WEATHER AT AIRPORTS IN WESTERN SLOVAKIA

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Abstract

Weather is limiting factor in planning of our activities. We often have to change our plans to avoid problems that the weather could bring. Transport, especially air transport is very sensitive to sudden changes of weather. For any mode of transport, safety, speed and efficiency is heavily dependent on current and expected weather conditions. Therefore, it is important to know very well the phenomena related to the atmosphere and selected mode of transport.

Keywords

Cold front, dangerous weather prenomena, aviation

1. Why frontal area is so dangerous?

Weather is one of the most critical factors relating to safe air transport. (Galieriková, Materna & Sosedová, 2018). One of the most dangerous weather events in the atmosphere in our latitudes is the movement of the frontal interface. (Dvořák, 2010). Frontal interfaces are related to the low air pressure area and can be divided into warm, cold and occlusive according to the prevailing processes in the atmosphere associated with them. Cold frontal interface is probably the most dangerous weather phenomenon for aviation.

When a cold front pass through the area, a cooler mass of air, which moves forward as a "front" replaces a warmer mass of air by lifting it as it passes. By lifting warmer air, the cold front helps to form a distinctive, often very massive, convection clouds. Because the cold front moves faster, often up to about 50 km / h, the cold front brings more intense weather (Zverev, 1986).

2. How could cold front be detected?

Cold cloud cover can be determined relatively easy.

There are cumulonimbus type clouds near the frontal line. Thunderstorms, heavy rains, and squalls are formed - especially in the summer months. In aviation, it is necessary to count on heavy icing, turbulence, electrical activity, downburst and also heavy rains and hail. Behind the front, one can expect the following cloud types:Ns, As, Cs, Ci. (Zverev, A)

In general, the cold front is more significant during summer days, when the conditions for air instability are the most suitable (Bednář et al., 1993).

3. How do individual meteorological elements change before arrival of the front?

The temperature is stable or slightly rises up before the arrival of the front. The temperature drops significantly after the transition, but it has a variable character in the rainfall zone.

Visibility is very good, it worsens in the rainfall zone, it is lower when there are heavy showers and thunderstorms. Atmospheric pressure steadily decreases with the approach of a cold front; with frontal passage, the pressure rises sharply. Before the arrival of a cold front, there are rain showers falling out of the cumulous clouds in the range of 50 - 100 km from the front line. After the passage of the cold front, the sky usually clears. The precipitation zone reaches approximately 200 km from the front line. Before the arrival of a cold front, the prevailing wind direction is SE to S. Wind speed increases with the approach of the front. Heavy winds are also typical. After the passage of a cold front, the prevailing wind direction is S to NW due to a cold advection that turns the flow to the left (Dvořák, 2010).

4. Work methodology.

METAR reports and reports from the SHMU Bulletins were used to analyse the occurrence of the Cold Fronts across the country and its occurrence at international airports in western Slovakia. Data from 2014 to 2017 were analysed for Bratislava, Piešťany and Žilina international airports. However, more detailed analysis would require data from a longer period of time, but these years will give us some idea of the behaviour of the advancing cold front in western Slovakia. Analysis of the meteorological information revealed:

In the period of 2014 - 2017, a total of 188 cold fronts were registered in Slovakia, an average of 47 cold fronts each year. The table contains numerical expression as well as the percentage occurrence of the phenomenon. The following information was recorded at the selected stations:

Table1: Summary of phenomena observed during the cold front process as analysed by METAR 2014-2017. Source: Author.

	Bratislava	**Piešťany**	**Žilina**
Strong wind	**161** **85 %**	**123** **65 %**	64 34 %
Lower visibility	69 37 %	98 52	95 51 %
Convective clouds/thunderstorm	52/28 thunderstorm 28 % / 54 %	28/14 thunderstorm 15 % / 50 %	43/35 thunderstorm 23 % / 81 %
Precipitation	75 40 %	82 44 %	**109** **58 %**

The table shows that the cold front most frequently occurred as a strong wind at the Bratislava and Piešťany airports. At the Airport Žilina, it occurred in the form of precipitation that impaired visibility. The least apparent phenomenon at each airport is convective clouds and thunderstorms, but this figure is greatly distorted by the storm season, which usually lasts in the warm months of the year - roughly from March to October. If TCU and CB cloud cover were not taken into account, the least visible phenomenon at Bratislava airport would be impaired visibility. In Piešťany, the phenomenon with the least occurrence is rainfall. In Žilina, the phenomenon with the least occurrence is strong wind, which occurred 3 times less in comparison with Bratislava and about 2 times less when compared with Piešťany. In the case of strong winds, there is a risk of crosswinds or wind shear, which can be dangerous during take-off and landing phases. It can also cause damage to the aircraft. Visibility in the event of very rapid deterioration, with the rapid onset of precipitation, is mainly a problem for VFR or less experienced pilots (Záhumenský, 1998). Thunderstorms, or globally convective clouds, are particularly dangerous due to severe turbulence, possible discharges, reduced visibility, showers and thunderstorms with a potential hailstorm. The storm also interrupts the airport operations because operations in storm could lead to injuries of ground personnel due to lightning strikes or another related phenomenon. The interruption of airport operations may have a significant effect on the delay of the check-in and therefore it negatively influences on the time performance of flights. Of course, all of the phenomena mentioned here may affect the overall delay or even diversions to other airports.

There are some aspects of the cold front evident from the analysis. The atmospheric pressure drops before the arrival of the front. After the passage of the front, the prevailing wind direction is W and NW, TCU and CB type clouds are present (especially in summer), permanent precipitation is present and temperature drops.

5. Conclusion

The weather changes gradually as the cold front progresses through the territory. Many of the weather changes are very evident and affect operational conditions of airports. When forecasting the progress of the cold front, meteorologists must take into account dangerous phenomena that are connected to the front and they vary between airports (Novák Sedláčková, 2018). A The proper forecast can improve the safety of air traffic and it can increase quality and comfort of air transport.

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