

AIR TRANSPORT SAFETY IN UAV OPERATIONAL CONDITIONS

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Abstract – The article presents the possibilities of using unmanned aerial vehicles in air transport. The use of UAVs in the airspace has become widespread, despite many implemented legal regulations, there are many incidents that threaten not only aircraft during the flight, but also the airport infrastructure. The potential threats and the chances of implementing remedial measures were analyzed. An attempt to evaluate the possibility of maintaining aviation safety at an appropriate level in the conditions of UAV operational conditions has been done. The main research problem was defined as follows: How would implementing unmanned aerial vehicles into the air transport system influence the acceptable level of safety? The article uses theoretical methods such as: system analysis, analysis and synthesis in the field of literature, analogy, comparative method. In terms of empirical methods, an original diagnostic survey was carried out, based on a selected group of people related to the explored topic. In addition, the observation method was used by the feedbacks and observations of the group of air traffic controllers from civil airports (located in Poland).

The article describes the current transformation of air transport, taking into account the planned modernizations. It presents the PansaUTM system as one of the countermeasures, monitoring and securing the movement in the airspace. Furthermore, the transponder issue was raised in relation to the enhancement of the UAV identification system, with a detailed explanation of the importance of the TCAS (Traffic Collision Avoidance System). Referring to the prospects for the development of air transport, the latest design concepts for cargo drones were presented. The issue of full transport autonomy of UAVs was analyzed based on the requirements of legal regulations. The comparison of benefits and threats in conjunction with the conducted empirical methods allowed for the development of conclusions confirming the research hypothesis and indicating the possibility of using remedial measures in the process of UAV evolution.

Key words – UAV, air transport, aviation safety, smart city

JEL Classification – K42, R41, R42, Z32

INTRODUCTION

Technological innovations of today are undeniably an opportunity for the future of our generations to be optimized by mechanisms. The constant evolution in the field of automation and mechanization of many industries, as well as everyday life, is closely related to the wide spectrum of functional solutions development, time optimization and rationalization of the human factor. Unmanned Aerial Vehicles (UAVs) and Unmanned Aerial Systems (UASs) fit into the concept of the now popular "smart city". The vision of a "smart city" has become a common tomorrow of the current world, which already accompanies us in everyday life - the examples of using drones for

the needs of local governments are proof of this.

One of the aspects of this concept is the significant share of drones in air transport. Cargo drones are increasingly used at airports around the world. Today, the coexistence of unmanned and manned aviation is a challenge not only for aviation authorities in terms of legislation, but above all for the security of airports and airspace users [1]. In relation to smart cities, drones can be a tool for monitoring highly urbanized areas from the air in order to ensure the safety of residents, control the observance of the principles of safe movement, support the activities of local governments in the process of air pollution analysis, monitoring the situation on the roads or locating the sources of fire during fires. These are just

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some of the potential components of unmanned aerial vehicles utilisation.

The presence of unmanned aerial vehicles in the airspace is becoming common today, and despite the regulations on flying in airport areas, there are many incidents that threaten not only aircraft during the flight, but also airport infrastructure. The combined system of unmanned and manned aviation must function in a way that ensures the highest standards of traffic flow safety in the airspace and meet the requirements for the protection of critical infrastructure.

Unmanned aerial vehicles are used, among others, in Australia to distribute medicines to inhabitants of rural areas. Drone transport also operates in Poland (e.g. the airport in Katowice). According to analysts, the logistics market with the use of drones will almost triple in a few years. We also hear that the Bulgarian Dronamics company uses Black Swan drones to transport loads weighing up to 350 kg over a distance of even several thousand kilometers. It is estimated that the cost of such a service can be reduced by up to 80% compared to a conventional cargo plane.

Therefore, risk assessment gradually becomes the essence of the correct use of UAVs. The dynamics of the development of new unmanned technologies increases the demand for threat analysis tools, the current situation in the field of airspace safety requires the use of a specific system for monitoring operator behavior and the continuous implementation of security measures. One of the recently introduced measures that fall under the name of remedial measures is the Polish PansaUTM system developed by the Polish Air Navigation Services Agency. The system enables, through a transparent panel, the coordination of unmanned flights and the integration of drones with other airspace users.

1. RESEARCH PROBLEM AND METHODS

The main aim of the article is to analyze the impact of the operability of unmanned aerial vehicles on air transport. Aviation safety is undeniably essential. Each of the conducted air operations must be carried out in accordance with strictly defined regulations and procedures. The increase in UAVs operating in the airspace, implementation of airport services, or plans for mass deliveries mean that normative acts and internal regulations have to be modified on an ongoing basis. What's more, the interest in drones that can be used to monitor smart cities from the air has recently increased in order to e.g. ensuring the safety of residents and monitoring compliance with road traffic rules. They also play an invaluable role in the search for missing persons, rescue operations, and supervision of infrastructure. The use of unmanned

aerial vehicles by public institutions creates many opportunities, however, certain risks include the need to ensure the physical safety of people and property during flights, as well as the protection of privacy. Air transport with the use of UAVs definitely creates the conditions for cost optimization and increasing the supply chain. However, one should remember about the risk generated in the conditions of air traffic congestion in relation to the possibility of safe performance of tasks by conventional aviation.

The main research problem was identified as follows: How UAVs affect safety and air transport options? The article uses qualitative and quantitative research methods:

- analysis and synthesis in the field of subject literature, legal acts, scientific publications, allowing for the systematization of issues related to the subject of research, drawing conclusions in terms of remedial measures,
- system analysis, enabled the evaluation of the complex problem of air transport safety in relation to its current capabilities,
- the analogy was used to explore the similarities between the issues of air transport,
- a comparative method on the basis of which the opportunities and threats for air transport were presented,
- the method of observation, implemented thanks to the opinions and observations of a group of air traffic controllers of civil airports (located in Poland),
- proprietary diagnostic survey, carried out on a selected target group related to the studied issue, a group of 10 people.

The presented methods allowed for the formulation of appropriate conclusions, which contributed to the confirmation of the hypothesis.

2. EMPIRICAL RESEARCH RESULTS

The article was mainly based on the author's research in the form of a diagnostic survey - a pilot survey was conducted with the participation of a group of 10 people. The indicated group was not a random group of respondents; it was selected in such a way as to obtain the opinions of people related to the operation of unmanned aerial vehicles, at the same time combining various industries and the status of UAV use (commercial, non-commercial, research). The empirical method used was to study the impact of the operability of unmanned aerial vehicles on aviation safety, including air transport.

In addition, Feltynowski's study "The use of unmanned aerial platforms in operations for public safety" [2] was used, which presents short interviews with air traffic controllers. The opinions point to security assessments

regarding the provision of zones near and within airports.

The study shows a clear conclusion that even a justified permit to perform tasks with a drone at the airport can hinder the work of people responsible for the regularity of air traffic and coordination of flights. Observations of KRL stationed at various civil airports suggest that the issue of irresponsible use of UAVs is becoming an increasingly serious factor generating risk for airports - its infrastructure, aircraft, personnel, and passengers themselves. Continuous observation and risk analysis as a permanent process are therefore

necessary conditions to maintain an adequate level of airport security. The table below proves the hypothesis put forward regarding the need for continuous risk assessment in relation to air traffic and extending UAV services through their active inclusion in the supply chain. The quoted, actual reports of air traffic controllers regarding the undesirable operability of UAVs at airports allow for drawing specific conclusions regarding the implementation of remedial measures in the field of the dynamics of unmanned technology development.

Table 1. Selected examples of dangerous situations described by the ATC of Polish airports during the questionnaire with open questions [2]

No.	Place of work of the ATC	Situation description
1.	Airport Warsaw – Modlin (EPMO)	'Often, a smartphone is used to operate a drone, which is also used for communication between the GSM operator - TWR. Operators treat the drone as a priority over communication with TWR.'
2.	Airport Poznań – Ławica (EPP0)	'Due to the nature of the flights (photos, measurements), UAV operators need more time for their operations than other space users using similar procedures (fireworks, lanterns, mass event lighting, etc.). The operators often abuse the time allotted for them (several minutes delay in reporting the end of the operation). As a result, it is impossible to be flexible (shorter time intervals for UAV operations - greater safety buffer for airplanes), there is also often the problem of not knowing the zones intended specifically for drones in order to determine the position of flights. At the same time, when a change in the traffic situation occurs, telephone contact is impractical (time of making a call, dialling the appropriate number, connection tone, communication on the change or withdrawal of consent, execution of the instruction by the UAV).' 'We had an interesting case recently. The Lech-Legia match, the Police are escorting Legia fans with a Mi-2 helicopter. Over the stadium, the police are preparing to secure the area and calling that they want to fly a drone. They get permission, which we have to withdraw after 15 minutes, because a helicopter is approaching the stadium... also a police helicopter, but knowing about the aircraft, we have to ground the drones.'
3.	Airport Gdańsk (EPGD)	'There is so much G-class space in Poland ... There is request to the drones to fly there, not in controlled spaces where they put other users at risk. Working as TWR ATC in the airport control zone from the ground to 1800 ft, I am not able to provide air traffic control to aircraft having a drone in the CTR over which I have no control. Safety first. The constant liberalization of regulations in favor of drones will be continued until the first serious accident involving a/c. Open the eyes of those who allowed it.' 'I support complete ban on drone flights in CTR. If there are commercial flights and there is the task to complete - please, let them pay PANSAs, ports and lines for closing the CTR for the designated time and then let them do what they need. I do not want (but according to today's regulations I am forced to) to take responsibility for CTR, in which something is happening that I have no control over.'
4.	Airport Lublin (EPLB)	'A complete lack of control over whether the drone is flying or not. Maybe the solution would be the obligatory use of an application such as Drone Radar by flying operators in the CTR, then on the image from this application, the controllers could have an up-to-date view of the situation.'
5.	Airport Rzeszów – Jasionka (EPRZ)	'The possibility of purchasing a UAV only with a permit and providing personal data should be considered – plus the option of monitoring the UAV position. Smaller, freely available UAVs should have a limited range from the operator so that they remain at a safe distance from the minimum flight altitudes of aircraft.'
6.	Approach Control Service (APP)	'In my opinion, the greatest threat posed by UAVs and flying models for air operations are operators without qualifications. They do not have situational awareness and are not responsible of the criminal liability facing them when they fly without qualifications and in prohibited spaces. In my opinion, applications such as DroneRadar, training and exams for obtaining UAV operators' qualifications allow to protect effectively air traffic against potential UAVs' threats. I suspect that most of the incidents are caused by the operators' ignorance of the possibilities and conditions of flying in destination place.'
7.	Airport Kraków – Balice (EPKK)	'Drone flights in CTR should be prohibited.'

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To sum up, threats appearing at airports require the implementation of appropriate countermeasures. Risk assessment at each stage of new technology development is a key issue in achieving implementation success. The multidirectional opportunities created by the dynamics of UAV development is undeniably a challenge for companies producing specific unmanned utility devices.

For the analysis of the results, I additionally used the exchange of experiences of flying personnel, with whom I had the pleasure to cooperate in the past (during my service at the 33rd Transport Aviation Base) and the observations derived from own autopsy during my flight internship as an aircraft navigator during his studies at the Military Aviation Academy.

The indirect goal of the research in the scope of this article is to present transport solutions in the world and to present the possibilities of using them in our country. In connection with the route concepts of the Polish Air Navigation Services Agency, modifications in the field of transport are realistically planned for

use, and thus for use in everyday life. This is definitely a great opportunity in terms of mobility, on the other hand, some solutions are controversial in terms of maintaining the Acceptable Level of Safety Performance (ALoSP), defined as the level of safety agreed by the State authorities, to be achieved in civil aviation in a given State, as defined in the national safety program, expressed in terms of safety targets and safety performance indicators [3].

Below I will refer to the proprietary diagnostic survey presenting the obtained results of the study. The survey was conducted in a traditional form, in the period May 4 - June 10, 2022. The survey consisted of 13 correct questions and 7 specific questions. I will limit the summary of the results to the most important issues in the field of the research topic.

With regard to the awareness of drone operators, as many as 80% of respondents said that we are dealing with people who are not fully aware of the risks that may be caused by the incorrect use of UAVs.

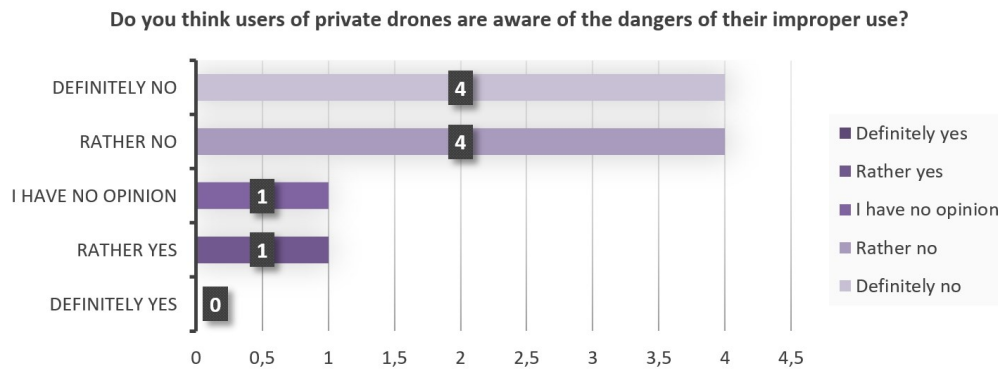


Fig. 1. Awareness of private drone users about inappropriate behaviour, n=10 (own study)

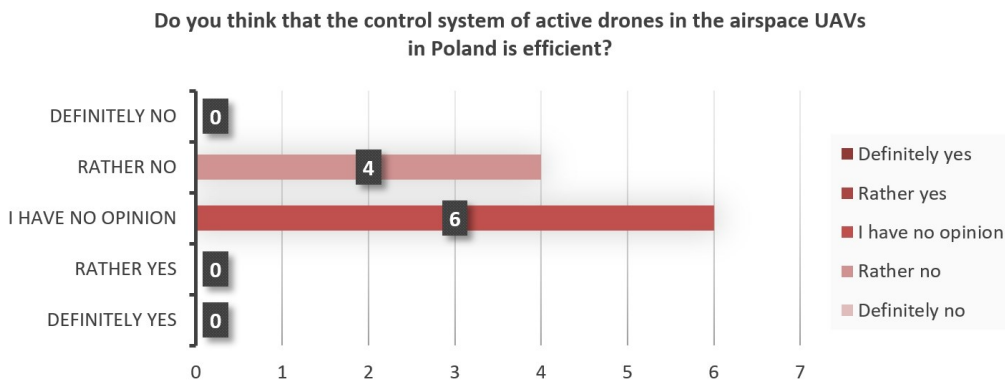


Fig. 2. Control system of active drones in the airspace UAVs, n=10 (own study)

The respondents practically unanimously stated that often the operators' behaviour in the air, especially about non-visibility flights (IFR), is not based on ensuring the maximum level in terms of an acceptable level of airspace safety. This result proves that with the deepening of the unmanned industry revolution, users should have adequately increased requirements in terms of obtaining permissions, or the use of drones (mainly amateur).

The above chart (Fig. 2) presents the opinion on the control system of active drones in the Polish airspace. The majority stated that they were unable to give a precise answer on the issue of the effectiveness of the national monitoring of airborne behaviour of operators. On the other hand, the others decided that the system of controlling the activity of active drones and enforcing penalties for the use of UAVs contrary to the intended use in Poland does not properly secure air traffic flows and airport security.

The chart below (Fig. 3) presents the knowledge of the countermeasures that can be used outside

our country. The following data show that the issue of the chance to implement proven solutions (e.g. in the West) is not currently in the spectrum of interest of national authorities.

When referring to the issue of opportunities for the development of new utility technologies in the field of disseminating unmanned aerial vehicles, the following evolutionary directions were most often indicated (listed in the hierarchy from the most to the least possible in common use):

- 1) Use on the battlefield, integrated defense UAV platforms - the future of the battlefield (e.g. the concept of Multi-Domain Operation) - all respondents estimated the direction of development as highly probable in common use;
- 2) Widespread use in terrorist activities, for the transport of hazardous materials;
- 3) Stratospheric drones replacing orbiting satellites;
- 4) Delivery of products ordered online (e.g. Amazon project);
- 5) Passenger drones - human transport.

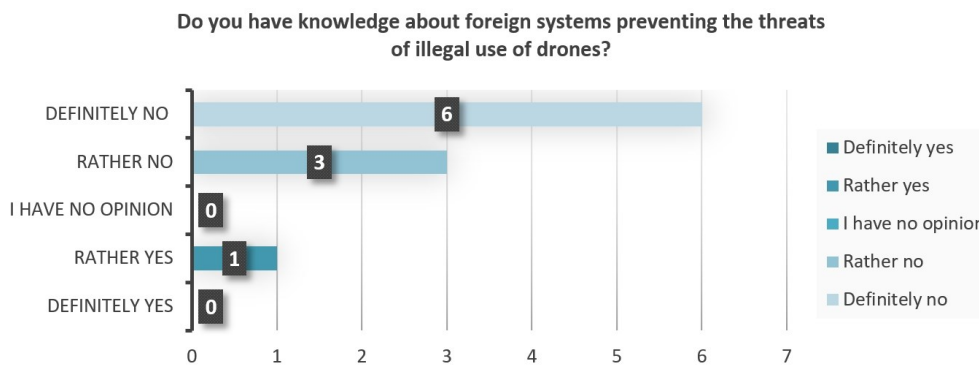


Fig. 3. Foreign countermeasures system (possibility of implementation in PL), n=10 (own study)

Table 2. Potential opportunities and threats indicated by the respondents resulting from the dynamics of unmanned aerial vehicles technology development (own study)

Opportunities	Threats
Improving transport, transporting products to hard-to-reach places, e.g. medicines, food in the mountains.	Terrorism - weapons, circulating ammunition.
They will replace people in the implementation of dangerous tasks (volcanic research).	Drug transportation.
Dynamic drones - an element of surprise during military operations.	Terrorism in terms of crime, accounts of criminal groups.
Fast and collision-free medical transport.	Use for own purposes of operators, not always in accordance with the intended use and production assumptions.
Improving the safety of people and the environment (monitoring of threats).	
Shortening supply chains, improving transport logistics.	
Improving mobility in medical transport.	
Working, completing tasks in difficult conditions.	Military double-edged weapon.
Use for precision military operations.	

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The results clearly show that most of the respondents see the need for UAV development mainly in relation to the application in the Armed Forces, defense systems and battlefield modernization (unanimously determined factor).

The respondents stated that the dynamics of the development of unmanned technologies, despite

creating many opportunities for the development of various industries, causes serious threats to the safety of airspace. The above data show that the hypothesis regarding the need for continuous analysis along with risk estimation and care for the implementation of specific remedial measures, and ultimately limiting the movement of "amateur" UAVs in airspace zones is confirmed.

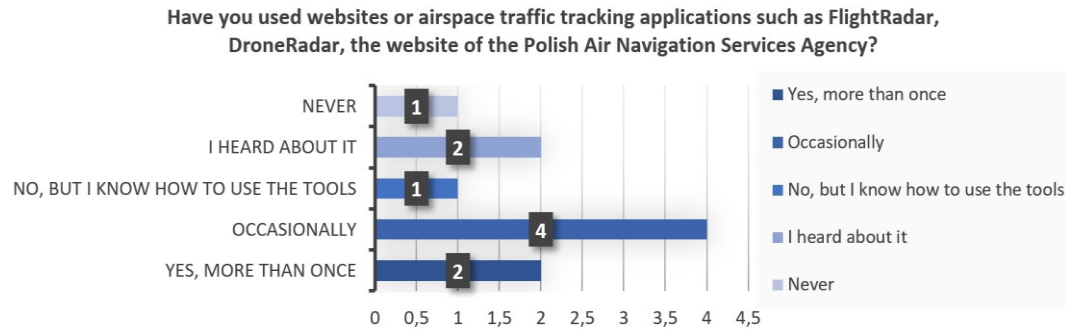


Fig. 4. Tracking the airspace traffic, n=10 (own study)

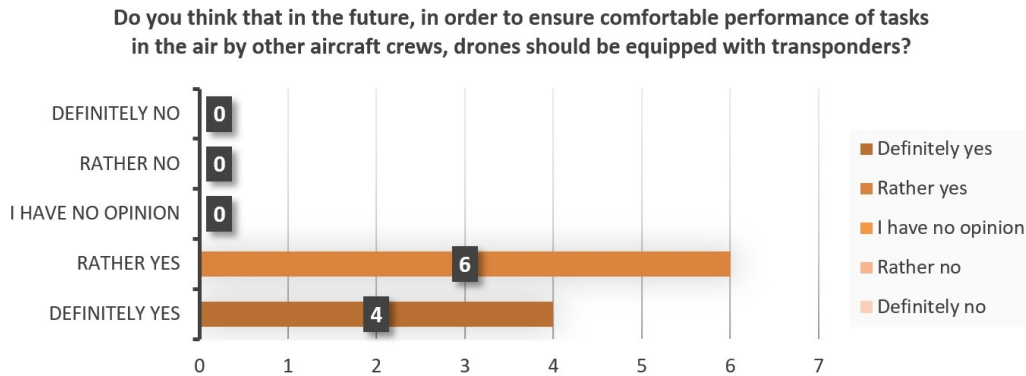


Fig. 5. The issue of equipping the UAV with a transponder, n=10 (own study)

The above charts prove that the public knows the tools for monitoring and observing UAV traffic in the airspace and knows how to check the safety conditions of a specific zone in the event of a planned operation with the use of UAV. Moreover, opinions were surprisingly consistent on the use of the transponder. The question was to check the level of advancement in the field of aviation knowledge and the relation to retrofitting the UAV (which of course involves costs and additional burden on the aircraft) in correlation with the maintenance of the highest safety standards in the air.

All respondents were in favour of maintaining the highest standards of using aviation safety, agreeing to retrofit their drones for complex tasks, with an appropriate load capacity. The results are a positive surprise, confirming the working hypothesis - they

constitute a professional and, at the same time, highly responsible approach of a selected group of users and people interested in UAV research to the issue of aviation safety and security [4].

The last question asked about activities aimed at creating conditions for optimal aviation safety in the case of active participation of drones in the airspace. The table below shows the most frequently typed answers (each respondent could indicate a maximum of 3 factors).

The above studies indicate the need to constantly monitor the current needs in terms of measures to prevent the misuse of UAVs. Unfortunately, what a year ago ensured the optimal standard of aviation safety, now may not be reflected in the desired Acceptable Safety Level (ALOSP).

Table 3. Aviation safety countermeasures in the operability of UAVs in the airspace conditions (own study)

Countermeasure	Number of votes
Increasing the legal standards in case of inappropriate use of drones by irresponsible operators	6
Increasing the age of obtaining entitlements (e.g. up to 18) in the open category	2
Verification of operators at the sales stage - selling drones only to people with Civil Aviation Authority permissions	6
Implementation of a modern system of countermeasures, especially in relation to airports	4
Increased detection of UAVs carried to the airport - detailed verification of the transported by air UAVs owners	2
Introduction of absolute neutralization of "unreported" drones flying outside their respective zones automatic system	6
Other: - prohibition of the operation of drones in airport zones (for drones not owned by the airport); - introducing a requirement to present practical skills for applicants for drone operator licenses.	2

The rapid development of unmanned technology in combination with the human factor (we are talking about the evaluation of the operators' intentions) forces a constant process in the process of extending the aviation safety system, maintaining the comfort of pilots and examining the operating mechanisms of the operators. In extreme cases - such as the issue of critical infrastructure, which includes airports - over time, the situation may require the exclusion of BSP traffic, excluding ships owned by airports from the restrictions. Here, however, there is the issue of retrofitting the airport drone in such a way that it is not sensitive to neutralization by jammers used to eliminate unwanted UAVs. According to the interviews, this controversial issue, in the opinion of many air traffic controllers, requires a solution in a short time.

3. TRANSFORMATION OF AIR TRANSPORT

Air transport is currently changing with the potential of unmanned aerial vehicles. Undeniably in many cases, the progress in the implementation of new cargo delivery tools indicates a whole spectrum of possibilities related to time optimization, immediate response in emergency situations, reliability without the use of the human factor, limiting the risk to human life in dangerous flight conditions (atmospheric factors, risk factors such as e.g. fire, no suitable landing pad).

Specialists say unequivocally that the drones used in cargo deliveries are the future. European and Polish companies are already competing for which of them will be first. This method of delivering goods is expected to contribute to supporting ecology, i.e. improving air quality by reducing pollution. Moreover, it is said on minimizing road traffic. From today's assumptions it follows that in the future drones are to commonly transport, among others mainly drugs, food, equipment

and clothing. However, it should always be remembered that despite the great opportunities to optimize transport costs, the operation of drones must take place within a certain legal framework and must not conflict with traditional air traffic. Here again the hypothesis put forward is confirmed that a system is needed that will help organize drone flights.

According to i24NEWS [5], in the second half of 2021, a media presentation was made in Israel, during which food and everyday food products were delivered. The action was organized as part of an initiative to create a supply network throughout the country. It was the third of eight planned phases of the national initiative. The next stage is about 300 daily flights over open areas. During the tests, the equipment will perform various tasks. The priority of the test is to deliver blood to the Sheba Medical Center in Tel HaShomer and to check the system with an analysis of airborne behaviour. The above-mentioned program is the result of cooperation between the Israeli Center for Industrial Revolution (C4IR) at the Israel Innovation Office, the Israeli Civil Aviation Authority (ICAA) and the Intelligent Transport Authority at Ayalon Highways, and the promotion of the use of drone services abroad (according to the information from "Times of Israel"). Summarizing the purposefulness of the project, the head of C4IR at the Innovation Authority stated that these activities bring closer the possibility of ordering food, clothes, medicines and other items using drones as part of a nationwide network that will be economically profitable for people, and will also help transfer some traffic from the road to the air. However, she added that the method brings with it concerns such as the danger to the birds and the possible dangers and difficulties of flying in residential areas. In her opinion, work on solutions to this issue is underway.

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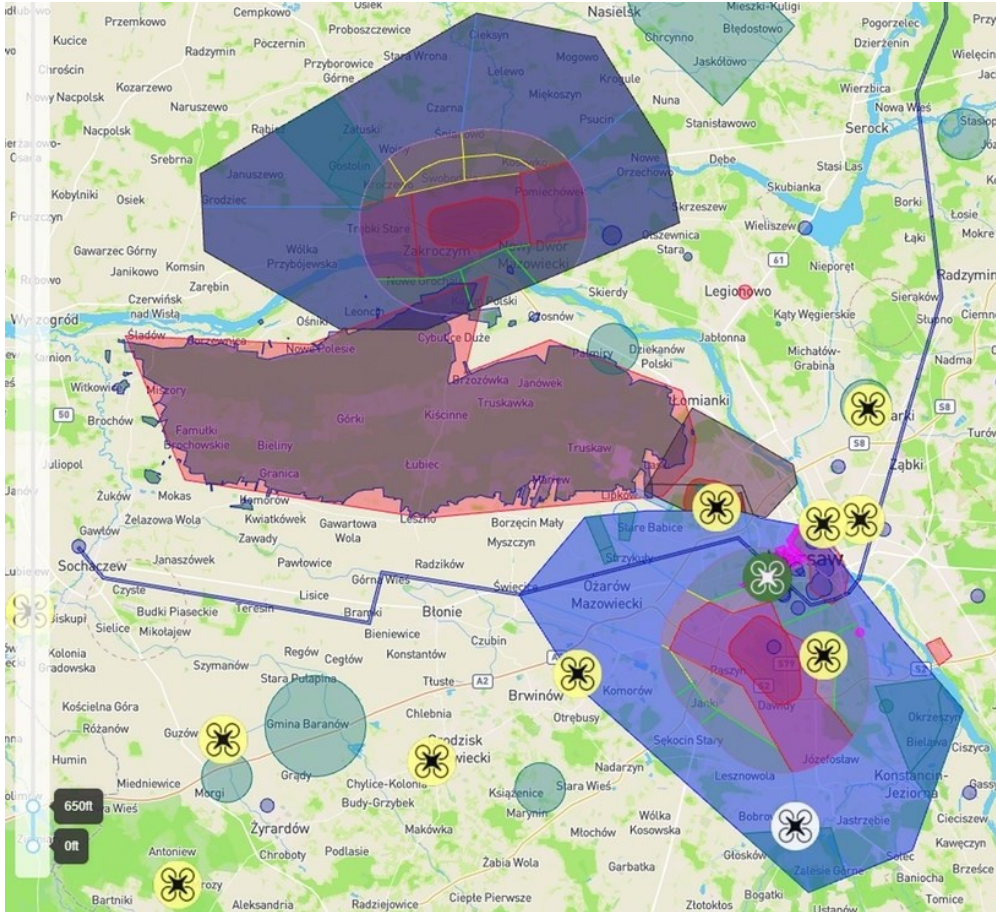


Fig. 6. UAVs' flight routes according to PANSA concept [6]

With regard to our country, according to recent reports, the Polish Air Navigation Services Agency has accepted domestic flights of autonomous transport drones. At the beginning, UAVs will autonomously cover long-distance routes between Warsaw and Sochaczew as well as Warsaw and Pułtusk. PANSA

informs that unmanned aerial vehicles will provide services to the health care system. Your shipments may contain blood, test samples or a small supply of medical supplies. According to a pre-prepared plan, these drones are to move between cities at speeds of up to 72 km / h, up to 6-7 times a day [6].



Fig. 7. EMILY [7]

In terms of saving lives on the water, an interesting example of the use of unmanned technology is the EMILY remote rescue robot from Green Valley, Arizona. EMILY was constructed in 2010 and is saving lives around the world. The name EMILY stands for Emergency Integrated Lifesaving Lanyard and is a remotely operated rescue boat [7]. It was invented by Tony Mulligan, CEO of Arizona-based marine robotics company Hydronalix. Since 2010, automated EMILY rafts have been used to rescue people in places like Los Angeles, but have never before been used to help refugees overseas. When EMILY was deployed to the Greek Red Cross, the robot helped more than 240 refugees safely reach land in the first 10 days in Greek waters. EMILY was designed to save lives on beaches, oceans, rivers and during floods. It also supports search and recovery missions using sonar technology. EMILY is a preventive tool, ready to be rescued at any time. Thanks to the unique structure of the platform, mobility and the possibility of carrying the boat by one person, EMILY is a quick response tool. All EMILY packages include:

- float cover,
- charger (2 pcs.),
- stand,
- the flag,
- battery module,

- 2.4 GHz transmitter controller with amplifier,
- lanyard (2 pcs).

Dr. Robin Murphy who is the director of CRASAR (The Center for Robot-Assisted Search and Rescue) and the Center for Emergency Informatics, aims to ensure that rescuers can send the robot the location of the victim through binoculars. The mechanism of action would be to transmit the victim's location to a computer that would convert the bearing and send GPS coordinates to the robot. In this way, an automated raft could come to help a person in need on the water automatically, without the intervention of a lifeguard. The manufacturer emphasizes, however, that from the point of view of a person in the water, it would be quite stressful if the red raft approached the injured person at a speed of 20 miles per hour.

Murphy is looking for ways to use thermal imaging cameras that could detect casualties in the water and automatically slow down an approaching raft, perhaps even turning the raft to aid grasping. In addition, due to the international use of the boat's potential, Murphy wants to develop a kind of smart screen on the side of the raft that would contain images and audible instructions available in multiple languages. EMILY technology definitively complements public safety teams and supports the potential of national security personnel.



Fig. 8. Robotic Lifeguard Named EMILY [8]



Fig. 9. Pars [9]

Staying on the topic of unmanned water transport systems, I would like to raise the issue of one more device - the work of the Iranian company RTS Lab, the Pars drone. Built on a Quadro copter, it can save drowning people's lives faster than a lifeguard. The device has lifebuoys attached, which are dropped near the drowning person. Due to the fact that the drone is an aircraft, it reaches the victim in a much shorter time than lifeguards. Pars can also easily operate at night because it is equipped with a thermal camera to detect the human body in water. In addition, it is equipped with LED lamp lighting, has a camera with a current view from the deck of a drone, autopilot, GPS, it is stabilized by a three-axis gyroscope, barometer and compass.

The constructors from RTS Lab did not forget about a dedicated water platform for the drone, where it could regenerate between rescue operations. The platform is equipped with solar panels, thanks to which Pars charges its batteries while it is docked on the platform. Moreover, the platform can accept

more than one drone.

According to the manufacturer's data, Pars can fly at a forward speed of approx. 7.5 m/s and float through 10 minutes, which gives it a range of 4.5 km. There were also real tests where Pars competed against a real lifeguard. It was checked when the drone and the man would reach the injured person 75 m away from the shoreline. Pars delivered a lifebuoy 22 seconds after being called, and a lifeguard in 91 seconds. The main reason why the Iranian company RTS Lab started working on the Pars drone was the very large number of drownings recorded each year in the Caspian Sea basin in the north of Iran.

The indicated examples of "automated rescuers" definitely revolutionize unmanned service of the injured. Speaking of progress in the field of UAV technology, it is necessary, however, to indicate a key transformation related to air transport, namely powerful cargo drones, in which large sums of money have started to be invested in the West.



Fig. 10. Natilus [10]

The start-up of Natilus from California is talking about massive autonomous cargo drones, which are to reduce air freight costs by 60% and reduce carbon dioxide emissions by 50%. The company announced that it had acquired pre-orders worth \$ 6 billion for more than 440 of these aircraft, and at least two will go to the fast-growing shipping company Flexport. Freight forwarders have to compromise between speed and cost when deciding how they want to transport cargo over long distances. Sending goods by air is undoubtedly faster - we can deliver goods in just one day, while shipping by sea would take weeks. On the other hand, air transport is six times more expensive than sea freight and generates significantly more carbon dioxide emissions.

Transport drones look very similar to airliners, with the wings placed close to the center of the fuselage. Most loads are shipped on rectangular pallets, so considerable space remains when the cylindrical cargo space is filled. Natilus cargo drones have diamond-

shaped cargo-bay surfaces, which allow them to hold up to 60% more cargo than standard aircraft of the same size. They have a more efficient blended wing design which should also make them more fuel efficient, leading to lower emissions. Cargo drones are also built for autonomous flight, meaning customers would not have to pay the crew to travel with them. However, until regulations allow full autonomy, they will have to pay someone to pilot the vehicles remotely.

Natilus conducted two rounds of wind tunnel tests to validate the design of its cargo drones. The company's goal is to ultimately produce four aircraft models: a short-haul version with a carrying capacity of 3.8 tons, a medium- and long-haul version with a carrying capacity of 60 tons and two long-haul versions with a carrying capacity of 100 and 130 tons. The smallest version of the drone will be the first to leave the production line, and deliveries are expected to begin in 2025 [10].

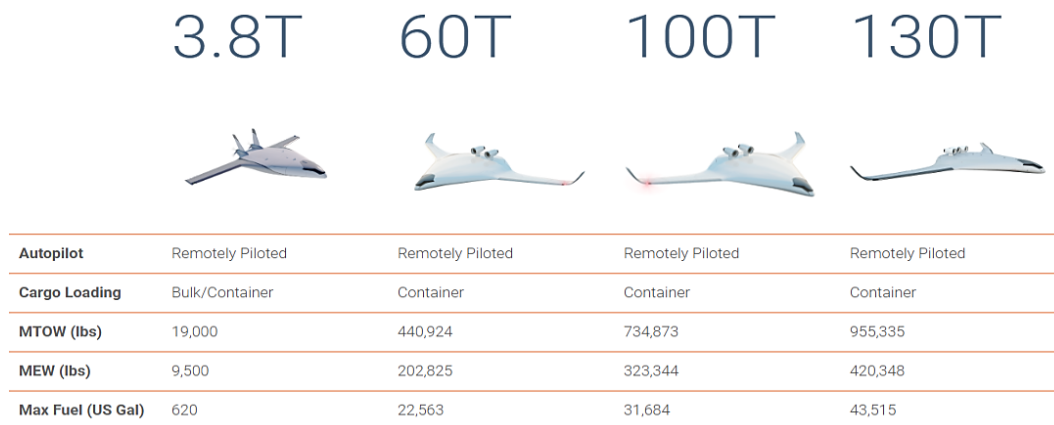


Fig. 11. Types of Natilus [10]

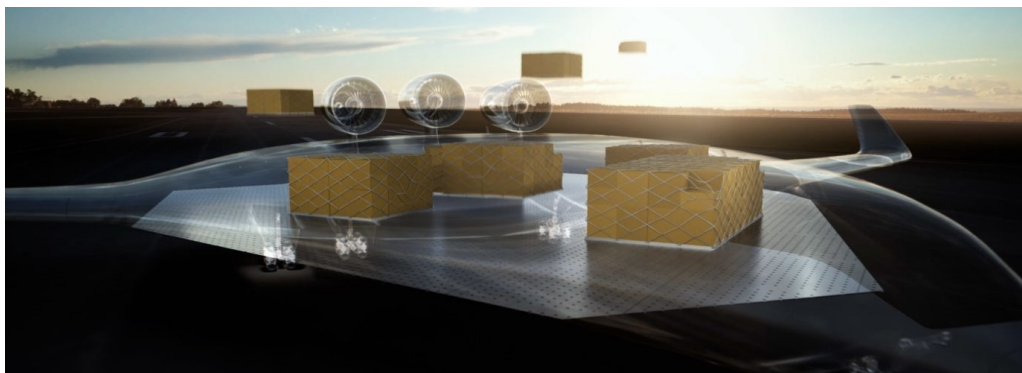


Fig. 12. Location of the cargo [10]

4. THREATS AND POSSIBLE REMEDIES

The aspect of aviation safety, as a priority issue, in the current conditions requires the use of a reactive approach, based on the analysis of recorded events, as well as a proactive approach, which consists in predicting possible threats. In addition to eliminating the danger, prediction is also aimed at, inter alia, development of appropriate methods and procedures of prevention, as well as mitigating the possible effects of threats [11, 12].

In terms of legislation and regulations regarding the proper use of UAVs, the following provisions are distinguished:

- 1) Commission Delegated Regulation (EU) 2019/945 of 12 March 2019 on UAS and third country UAS operators [13];
- 2) Commission Implementing Regulation (EU) 2019/947 of 24 May 2019 on the rules and procedures for the operation of unmanned aerial vehicles [14];
- 3) Guidelines of the President of the Civil Aviation Authority [15-17].

The threats from the operational UAV depend on the place of appearance in relation to the aircraft and infrastructure. Even an amateur UAV can cause a dangerous situation due to the weight or distraction of the pilot from the performed tasks. UAVs may have a negative impact on the airport infrastructure and disrupt the operation of data exchange systems - UAVs with built-in hazardous equipment (GPS jammer). Jammer, i.e. A jammer is an electrical or electronic device whose purpose is to prevent other devices from effectively communicating over a specific band in the area of operation of the jammer. In this way, a UAV equipped with a jammer can cause interference to aviation systems, e.g. positioning based on GPS / GNSS. In addition, the actually recorded events include, among others: flight in a drone equipped with film equipment (UAV mass: 7 kg) in the axis of the instrumental approach, flight and dropping a flare on the military part of the airport, UAV flight in the immediate vicinity of runways, flight at a distance of 100 m from a passenger plane, flight with image and sound recording directly on the runway of taking off and landing planes, flight approximately 6.1 m (20 feet) from the wing of an Airbus A320 approaching landing at H = 200 m [18, 19].

An appropriate possible solution would be to increase the control of operators at the sales stage. To conclude the results of the interviews conducted among the KRL personnel, we can easily judge that the operators' awareness leaves much to be desired. The user sector - UAV operator should in the future be monitored already at the stage of purchasing the drone.

A debatable topic in the matter of remedial measures - here, UAV identification in the airspace is the installation of a transponder on remotely piloted aircraft. In the opinion of many pilots, this would be a solution enabling effective UAV identification while performing tasks in the air. The principle of operation of transponders is hidden in their name: it comes from the words transmitter and responder. This means that the device is used to receive the signal, process it, amplify it and send it back, that is, it creates a kind of response to the received signal, all in real time. A transponder commonly used in aviation is the basic equipment of every aircraft in controlled airspace. In the event of an aviation, the device receives a signal from ground radars belonging to the air traffic control system (ATC System). Then the signal is processed, i.e. more precisely enriched with various data about the aircraft in which it is located, and then, after additional amplification, it is sent to the ground in the form of a response, and the transmitted information is displayed on the radar or computer of the air traffic controller.

Thanks to the transponders, ground crews (KRL) know "live" the exact location of the aircraft in three dimensions, including altitude, as well as other data, such as the speed at which the object is moving. The devices also play other very important roles:

- 1) Thanks to it, we can see live air traffic in the world (e.g. in the Flightradar24 application),
- 2) Send a special transponder code to the ground,
- 3) Form the basis of the operation of the TCAS system.

TCAS (Traffic Collision Avoidance System). This system is installed in many airplanes, especially large ones (transport, passenger). A warning will appear on the system screen when two machines are close to each other. And when the planes are dangerously close and at the same altitude, the system in one machine tells the pilots to fly up, and on the other to descend. It is a solution for mistakes made by air traffic controllers, and a transponder is necessary for its operation. The transponder code (Squawk), on the other hand, is a special octal number (counted from 0 to 7) by which controllers can recognize the aircraft. The transponder code is unique to almost every aircraft and contains more detailed information about the machine. When the transponder sends its code in response to the signal, the controllers on the ground can see, among other things, flight number or aircraft model.

The Polish Air Navigation Services Agency perfectly understands the changes taking place in today's airspace. One of PANSAs's strategic goals is to create an appropriate environment for the further development of the UAV services market, and thus the implementation of the European U-space concept assuming safe and

effective integration of operations performed by drones with manned air traffic. To achieve this goal, it is required to create a system enabling electronic coordination of UAV flights and digital management of applications and consents for flights in the airspace. PansaUTM is a digital concept of UAV flight coordination and digital management of requests and approvals for flights in the airspace, which consists of PANSA's proprietary operational solutions and a system part, integrated with the mobile application. PansaUTM, which is a source of superior information and aeronautical data, is a system that facilitates the process of BSP flight coordination, providing information related to operators, their permissions and drones, and, if necessary, the possibility of assessing applications for UAV flights. The PansaUTM system with the dFPL (drone Flight Plan) functionality, i.e. digital BSP flight plans, also allows for electronic creation of out-of-sight BVLOS (Beyond Visual Line of Sight) missions and VLOS (Visual Line of Sight) missions in accordance with applicable regulations, topography and current air conditions. The created mission, primarily for the controlled space, is analyzed by the system in order to issue digital approvals for the indicated UAV flights at the pre-tactical level. This process is performed fully electronically in real time, detecting potential airspace conflicts at the strategic level and improving the planning, verification and approval of BSP missions. The heart of the PansaUTM system is the air traffic control interface and support for the provision of safe air navigation services [20].

The PansaUTM system also includes the ability to

e-identify and locate the drone in real time, when it has one of the selected tracking methods, dynamic geo-fencing that allows selected UAV operators to land, as well as direct, two-way, non-verbal communication on the line of the air traffic service - operator BSP through the so-called CDDL (Controller-Drone Data Link Communication), creating conditions for deconflict at the tactical level. The PansaUTM system reduces the burden on air traffic services while preparing for the expected increase in UAV operations in the future. The system was designed to provide the current level of safety to other airspace users. It shall be serviceable by the airspace manager responsible for the volumes of the controlled airspace. The modular architecture of the PansaUTM system allows for its full or partial implementation, in accordance with the current and future requirements and needs of users, as well as adaptation due to the language and changing regulations (e.g. various national laws or common European regulations, supporting U-services). At the same time, it is compliant with the existing provisions on the protection of personal data (e.g. GDPR) and compatible with the existing ATM (Air Traffic Management) solutions used by civil and military airspace and manned air traffic management entities. As part of PANSA, the PansaUTM system is integrated with the PANDORA system to display aeronautical information and the CAT system to manage airspace structures in real time. The PansaUTM system also enables integration with other U-space service providers, such as local DTM (Drone Traffic Management) systems through open API interfaces.

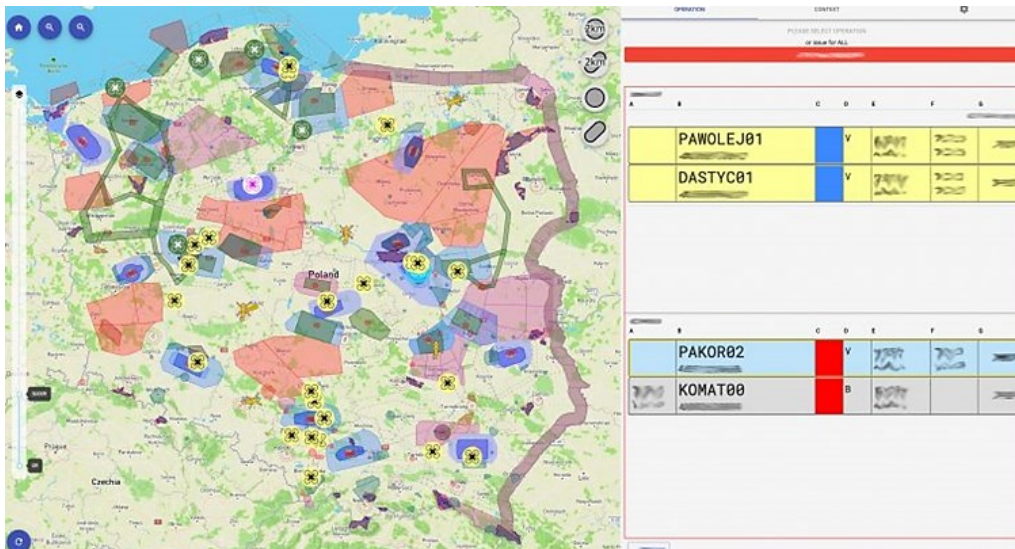


Fig. 13. PansaUTM [21]

Air transport safety in UAV operational conditions

In summary, PansaUTM is an operational coordination system for unmanned aerial vehicles. It is compatible with ATM (Air Traffic Management) solutions used by civil and military airspace managers and manned air traffic. It is a safe, complete, flexible, consistent and open solution. The system has successfully passed the accreditation process conducted by PANSAs, supervised by the Polish Civil Aviation Authority. In 2020, PansaUTM operationally implemented the PansaUTM system in the controlled zones of airports in Bydgoszcz, Gdańsk, Katowice, Kraków, Lublin, Łódź, Modlin, Olsztyn, Poznań, Rzeszów, Szczecin, Wrocław and Zielona Góra, as well as in the air information sectors FIS Gdańsk, Kraków, Olsztyn, Poznań and Warsaw. This means that all of Poland is within the range of PansaUTM services. Mobile access to the PansaUTM system is provided by DroneRadar. The application is available in Google and Apple stores under the two names Drone Radar and Drone Radar Premium.

CONCLUSIONS

Taking into account the fact that the capabilities of BSP are constantly growing, the idea of using them for broadly understood transport becomes justified. Such a solution will in many cases reduce costs, significantly shorten the waiting time for goods and perhaps in the future it will speed up the transport of people. The legal system has not kept pace with the dynamics of the drone operation potential in the airspace. More and more often, one hears about the damage caused by BSP, which prompts reflection in the area of operator liability, including insurance [21, 22]. A clear conclusion is drawn that the observations from the airports indicate the need for gradual improvement of the security system. The adaptation of legal regulations and the tightening of sanctions for violating the regulations on the use of UAVs seem to be a key issue at the moment. It is appropriate to use a reliable risk analysis along with its estimation in order to supplement the provisions regulating the increase in penalties for illegal entry into the CTR zone. In extreme, the situation may require certain zones to be prohibited.

As the number of UAVs increases, the conflict between the limited resources of low-altitude airspace and the unlimited activity of the UAV will become more and more visible. The rapid expansion of innovative unmanned aerial vehicles and their participation in the development of the global market mean that they enjoy a constantly growing interest among commercial and private operators.

Due to the complexity of the urban environment, privacy policy and public safety, the operation of unmanned aerial vehicles in urban areas is still in the exploration phase. It should be emphasized that the

airspace capacity in the cities where airports are located is limited. Nevertheless, despite the advancement of the process of planning public air routes for unmanned aerial vehicles (the cited research on transport using UAVs, including the mentioned results of C4IR, Natilus, Amazon), the prospect of such a solution is feasible based on interdisciplinary technologies, such as RS (Remote Sensing - remote sensing, used to obtain information about objects), GIS (Geographic Information System - an information system for entering, collecting, processing and visualizing geographic data) and mobile communication. According to Markets & Markets analysts, the global logistics and transport market with the use of drones in 2022 will generate revenues of over USD 11 billion. By 2027, the turnover of this market is expected to increase to over USD 29 billion. Therefore, the cost optimization is huge, and thus the demand for the implementation of the solution is growing. However, it is necessary to consider the issues of conventional aviation safety, the possibility of safe flights, the training of crews in new threats and operating in a combined system: airplane pilot - drone operator.

After constructing an appropriate UAV traffic management system, monitoring the situation in real time, unifying task planning and making a reasonable allocation of airspace, the vision of safe cargo transport by registered UAVs and drone operability that does not threaten other aircraft is achievable. However, this is a highly complex task, dedicated to highly developed countries due to the costs generated in the exploration and implementation process, and the effectiveness of its implementation requires a reliable risk analysis and its estimation.

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TRANSPORT LOTNICZY W WARUNKACH OPERACYJNOŚCI BSP

W artykule zaprezentowano możliwości wykorzystania bezałogowych statków powietrznych w transporcie lotniczym. Dokonano analizy potencjalnych zagrożeń oraz szans wdrożenia środków zaradczych. Podjęto próbę ewaluacji możliwości utrzymania bezpieczeństwa lotnictwa na należytych poziomach w warunkach operacyjności BSP. Główny problem badawczy został zdefiniowany następująco: W jaki sposób implementacja bezałogowych statków powietrznych do systemu transportu lotniczego wpłynie na utrzymanie akceptowalnego poziomu bezpieczeństwa? W artykule zastosowano takie metody teoretyczne jak: analiza systemowa, analiza i synteza w obszarze literatury, analogia, metoda porównawcza. W zakresie metod empirycznych przeprowadzono autorski sondaż diagnostyczny,

realizowany w oparciu o wytypowaną grupę osób związaną z badaną tematyką. Ponadto zastosowano metodę obserwacji, realizowaną dzięki opiniom i spostrzeżeniom grupy kontrolerów ruchu lotniczego lotnisk cywilnych (rozlokowanych na terenie Polski). Artykuł opisuje obecną transformację transportu lotniczego z uwzględnieniem planowanych modernizacji. Przedstawia system PansaUTM jako jeden ze środków zaradczych, monitorujących i zabezpieczających ruch w przestrzeni powietrznej. Ponadto poruszono kwestię transpondera w odniesieniu do wzmocnienia systemu identyfikacji BSP, ze szczegółowym wyjaśnieniem znaczenia systemu zapobiegającego zderzeniom statków powietrznych TCAS (Traffic Collision Avoidance System). W nawiązaniu do perspektyw rozwoju transportu lotniczego zaprezentowano najnowsze koncepcje konstrukcyjne dronów cargo. Analizowano kwestię pełnej autonomii transportowych BSP w oparciu o wymogi regulacji prawnych. Porównanie korzyści i zagrożeń w połączeniu z przeprowadzonymi metodami empirycznymi pozwoliły na wypracowanie wniosków potwierdzających hipotezę badawczą oraz wskazanie możliwości zastosowania środków zaradczych w procesie ewolucji BSP.

Słowa kluczowe: BSP, transport lotniczy, bezpieczeństwo lotnictwa, smart city

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