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An Analysis of the Factors Affecting the Number of Safety Incidents in Civil Aviation

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Abstract

Aviation is the youngest of the transport industries, yet despite its short history, it is considered one of the most important spheres of transport, both in terms of passenger and cargo transportation. Civil aviation is used by an increasing number of people, and the number of aircraft used by airlines around the world continues to grow. An inherent element that is a particularly important aspect of this mode of transportation is security. In civil aviation, there are numerous dangers associated with events occurring before the flight, during the flight, as well as those associated with the landing process. The events need to be controlled and their causes actively sought and ultimately prevented. The Polish Civil Aviation Authority, as part of the creation of the National Civil Aviation Safety Program, developed the National Safety Plan 2020-2023. The document covers threats identified in the Systemic, European, and National Areas. They are characterized and classified based on the materiality (significance) of the event. The aim of this article is to characterize and analyze selected factors (e.g. collisions with birds, helicopter events) that affect the number of safety incidents in civil aviation. The background of the study was the analysis and synthesis of the literature on the subject, while the main research method was the statistical analysis of historical data on aviation incidents. The data provided in Poland's National Security Plan 2020-2023 were used to distinguish the factors associated with the threats present and synthetically evaluate their impact. The analyses made it possible to identify areas of particular safety risks and form the basis for further detailed research.

Keywords

air transport, civil aviation, safety incidents, transport safety

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1. Introduction

Aviation has developed rapidly and is now one of the most important transportation industries. The number of flights performed each year is increasing (Menon, 2019). Air transport is used extensively for both passenger traffic and the movement of material goods. Air travel is generally considered to be very safe, however, as with any mode of transportation, there are incidents that threaten the safety of flying (Denney et al., 2019).

Therefore, the problem of aviation safety is frequently addressed in literature on the subject. In a general way, focusing on the assessment of risk and safety in civil aviation, the causes of aircraft accidents were described by Janic (2000). The article takes into account factors such as air, water, soil or noise pollution, waste management and congestion. A similar
analysis was made by Janic together with Netjasov (2008). Their publication presented an overview of existing research on risk and safety modeling in civil aviation. Cui and Li (2015), on the other hand, focused on the issue of safety efficiency in civil aviation in their publication. This article proposed an efficiency model, taking into account labor, capital, funds, and technology.

Ni et al. (2019) focused on major accidents and incidents affecting aviation safety. Their publication proposes forecasting the number of hazardous events using deep learning methods based on Big Data resources. In contrast, Greenberg et al. (2005) proposed the use of a Bayesian Belief Network to study civil aviation accident rates. The model considered the influence of airline policies and social behavior patterns.

In his article, Zieliński (2010) focused on the airport as a place where security issues are addressed by both state and non-state actors. He described the services responsible for maintaining security and their duties. By contrast, Szafran (2018) highlighted the relationship between decision-making and safety in aviation in his publication. Publications on aviation safety also consider the area of cybersecurity (Cieślak, 2016). Cyber threats in aviation are a serious concern and are no less significant than threats directly related to the physical control of the aircraft.

The considerations contained in this article concern Polish civil aviation. The authors focused on the issue of air transport safety. The essence of the National Aviation Safety Program is described, and data from the National Safety Plan 2020-2023 are used to analyze factors affecting safety (only such data was made available to the authors). Information concerning the National Threat Area was also used. The aim of this article is to characterize and analyze selected factors that affect the number of safety incidents in civil aviation. The background of the study was the analysis and synthesis of the literature on the subject, while the main research method was the statistical analysis of historical data on aviation incidents.

As part of the analysis, information was obtained on the type of threats occurring most frequently in Polish civil aviation. The study provides a basis for further detailed analyses, allowing us to identify and foresee threats as time series models, based on more accurate data, from a wider time interval. Research can also be expanded to include threats from the Systemic and European Threat Areas. Similar analyses can also be conducted for other modes of transportation.

2. The issue of safety in civil aviation

The concept of safety can be defined depending on a specific area. Safety is usually defined as a condition in which the risk of harm to a person or property is reduced to an acceptable level or is below such a level. Moreover, it is maintained at that level (or lower) through continuous processes of hazard identification and risk management (Ilków, 2011). Therefore, it is undeniable that safety is closely related to dynamics -especially in the aspect of both building it and providing it. In view of this, safety manifests itself mainly in actions implemented against threats and those that mitigate risks (Bielski & Krawczyk, 2010).

In "Leksykon wiedzy wojskowej" [The Lexicon of Military Knowledge] (Auerbach, 1979), flight safety is defined as certain conditions that ensure that an aircraft performs its flight without endangering the safety of the crew, passengers, and the aircraft itself, as well as the population and facilities on the ground. Safety in air transport is also defined as a property of a system to operate under certain environmental conditions without the occurrence of accidents and adverse events (Żurek, 2009). Flight safety can be attributed to the following characteristics (Łuczak et al., 2016):

- loss avoidance;
- no accidents or incidents;
- ensuring that flight operations are conducted in such a way as to avoid unnecessary hazards;
- controlling and maintaining risk at an appropriate level;
- people's attitudes toward unsafe activities and conditions;
- error avoidance;
- compliance with regulations and institutions.

However, flight safety is primarily defined by the relevant international and state institutions. Appendix 19 of the Convention on International Civil Aviation, entitled "Safety Management", provides the definitions of key terms related to civil aviation safety. In this document, safety is described as a state in which the risks associated with aviation activities have been reduced to an acceptable level and are kept under control. A hazard is defined as a condition or object that has the potential of causing or contributing to an incident or accident. An incident is defined as an event, other than an accident, associated with the operation of an aircraft that has (or could have) an impact on safety. An accident is an event in connection with the operation of an aircraft in which any person is killed or seriously injured, the aircraft is damaged or its structure destroyed, or the aircraft is lost or inaccessible.

There are five main elements in aviation that are sources of safety risk. These are represented in the 5M model. This model includes:

- human factor (Man);
- aircraft and related technology (Machine);
- operating space (Media);
- Mission;
- Management (Szymaniec, 2018).

Adequate control of and response to the elements listed above can have a positive effect on safety management in civil air traffic (Kasianov & Goncharenko, 2018).

In Poland, the authority responsible for civil aviation safety is the Civil Aviation Authority. It is a state institution, which is a government administration body responsible for civil aviation matters.

3. Hazards in Polish Civil Aviation – Safety Program and Plan

3.1.Poland's National Civil Aviation Safety Program

The Civil Aviation Authority defines its primary objective as ensuring a high level of safety in civil aviation. The institution wants to achieve it, among others, through the implementation and development of the National Civil Aviation Safety Program (NCASP). The purpose of the NCASP is to accomplish the integration of the state's safety management activities in the areas of both legislation and state policy and objectives and to promote safety and oversight of safety management systems.

The document provides information on safety oversight in civil aviation. The modern approach to safety is based on a safety management system and a national safety program. The system assumes that appropriate preventive actions are taken that can protect the aircraft from the threat.

The National Civil Aviation Safety Program incorporates regulations introduced by the International Civil Aviation Organization regarding the Safety Management System. It also complies with European regulations. The European Parliament, together with the Council of the European Union, has established rules related to safety management in civil aviation. National regulations are based, among others, on the Act of July 3, 2002, Aviation Law (Journal of Laws of 2020, item 1970) and on Article 30 of the Regulation of the Minister of Infrastructure of October 9, 2020, on the control of compliance with regulations and decisions in the field of civil aviation (Journal of Laws of 2020, item 1843).

The document describes the investigation of air accidents and the responsibilities and powers of state authorities. Importantly, it also describes a mandatory system for reporting aviation events.

3.2. Poland's National Safety Plan

The National Safety Plan 2020-2023, on which this study is based, is an appendix to Poland's National Civil Aviation Safety Program. It includes data on aviation accidents from 2011-2019 and such data were used in the presented study. The purpose of the document is to indicate the areas of risk that should be covered by the procedure of detailed analyses and supervision of the President of the Civil Aviation Authority. The Safety Plan draws information about the sources of hazards from sources operating at three levels. At the global level it is the Global Aviation Safety Plan. Meanwhile, at the European level, it is the Regional (European) Aviation Safety Plan. The third level is the national level, which is considered in this paper. National hazard areas include:

- collisions with birds;
- threats from animals;
- unmanned aerial vehicle operations;
- blinding the pilots with lights from the ground;
- aircraft events related to glider towing;
- performing operations with limited visibility;
- events involving the transportation of hazardous materials;
- helicopter events;
- Foreign Object Damage (FOD) events.

This paper analyzes the number of events that occurred in civil aviation between 2011 and 2019 that are listed on the National Hazard Register. The hazards noted can be described as:

— accident – an event in which any person is injured, an aircraft is damaged, an aircraft is lost;
— serious incident – a near-miss event;
— incident – an event, other than an accident, related to the operation of an aircraft that may affect safety;
— event – a situation occurring in air traffic, not assigned to any other group.

4. An analysis of the factors affecting flight safety

Aviation is steadily gaining popularity and, despite its short history, it is growing rapidly as a branch of transportation. Over the years 2011-2019, the number of flight operations has steadily increased (Figure 1).

Figure 1. The number of flight operations from 2011 to 2019. The author's own elaboration based on: Civil Aviation Authority (2020). National Safety Plan 2020-2023. Appendix to the National Civil Aviation Safety Program.

The data shown in the chart refer to domestic and international passenger traffic, charters and regular connections. Nearly 1/3 of the presented operations were performed by Polish carriers. There was a noticeable increase in the number of flight operations throughout 2011 and 2012. There was a decrease in 2013, but the chart shows a steady increase in subsequent years. The number of operations recorded in 2019 amounted to 398,073, the highest to date. The cumulative growth in the number of flight operations during the period under review was over 61%.

As the number of flight operations increases, so does the number of passengers using air transportation. The data presented also refer to domestic and international passenger traffic, charters as well as regular connections. About ¼ of passengers used Polish carriers (Fig. 2).

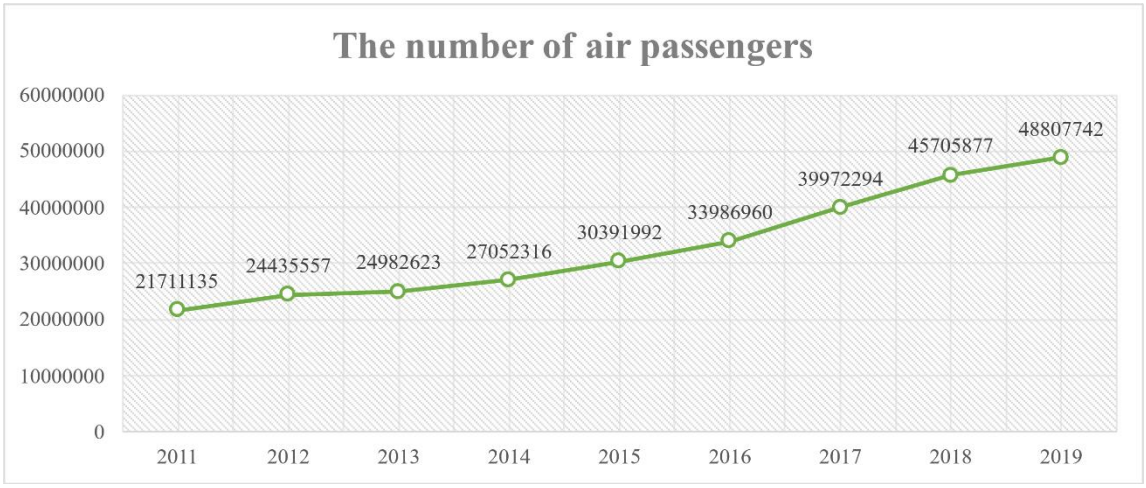


Figure 2. The number of air passengers from 2011 to 2019. The author's own elaboration based on: Civil Aviation Authority (2020). National Safety Plan 2020-2023. Appendix to the National Civil Aviation Safety Program.

The chart showing the number of passengers is strongly related to the chart showing the number of flight operations. The increase occurred in late 2011 and early 2012. There was a decrease in 2013, and a steady upward trend is evident in subsequent years. In 2019, 48,807,742 passengers used civil air transportation. It was determined that the cumulative passenger growth between 2011 and 2019 was nearly 125%. The number of aviation events increased steadily during the study period. In 2011, 1,601 cases were reported, and in 2019, as many as 5,838 aviation events were reported (Figure 3).

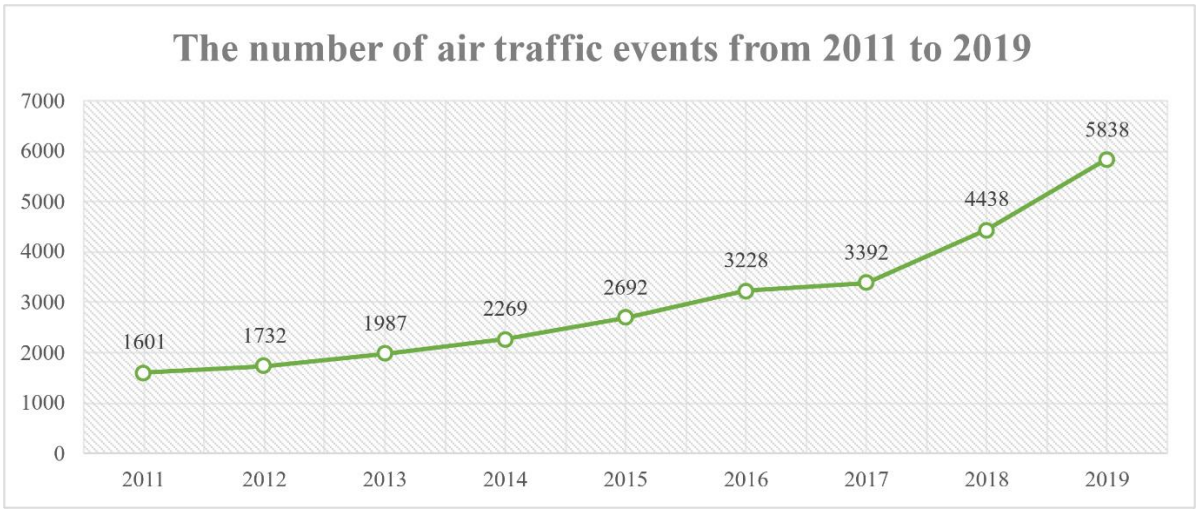


Figure 3. The number of air traffic events from 2011 to 2019. The author's own elaboration based on: Civil Aviation Authority (2020). National Safety Plan 2020-2023. Appendix to the National Civil Aviation Safety Program.

Civil aviation accidents and serious incidents were also reported from 2011 to 2019 (Fig. 4).

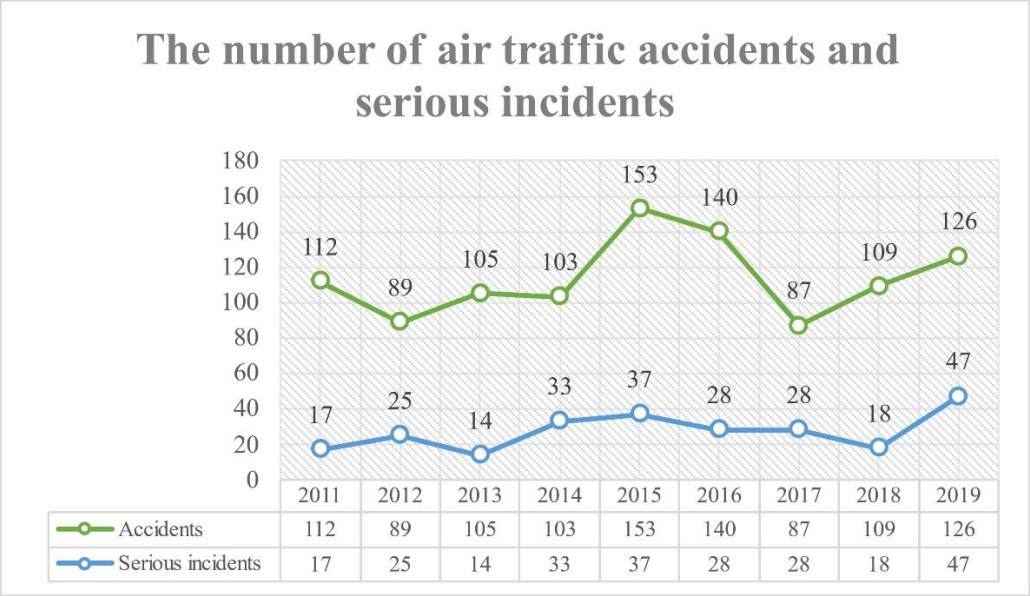


Figure 4. The number of air traffic accidents and serious incidents from 2011 to 2019. The author's own elaboration based on: Civil Aviation Authority (2020). National Safety Plan 2020-2023. Appendix to the National Civil Aviation Safety Program.

The average number of accidents is 114 per year, the average number of serious incidents is 27. In contrast, the average total number of accidents and serious incidents is 71 incidents per year. The highest number of such events occurred in 2015 and 2016.

The National Hazard Area identifies birdstrike events as the first of the threats. Events of this nature did not result in an aircraft accident during the study period; however, there was a nearly fivefold increase in birdstrike incidents between 2011 and 2019 (Figure 5).

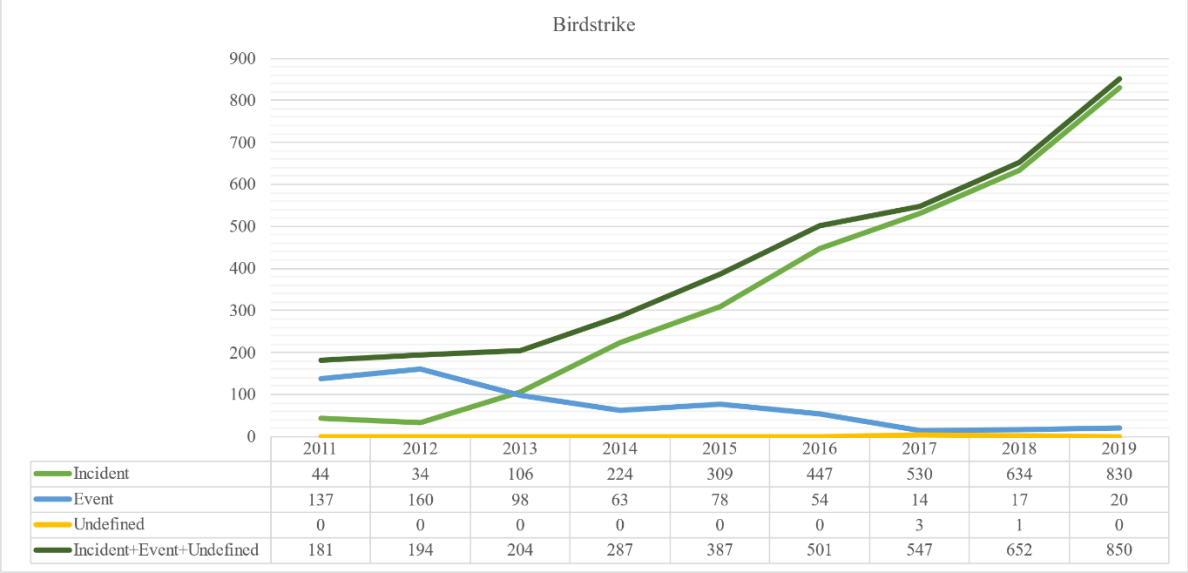


Figure 5. The number of birdstrike events in air traffic from 2011 to 2019. The author's own elaboration based on: Civil Aviation Authority (2020). National Safety Plan 2020-2023. Appendix to the National Civil Aviation Safety Program.

In 2011, there were only 181 events and incidents related to bird-aircraft collisions. However, the number steadily increased, and as many as 850 events of this nature were reported in 2019.

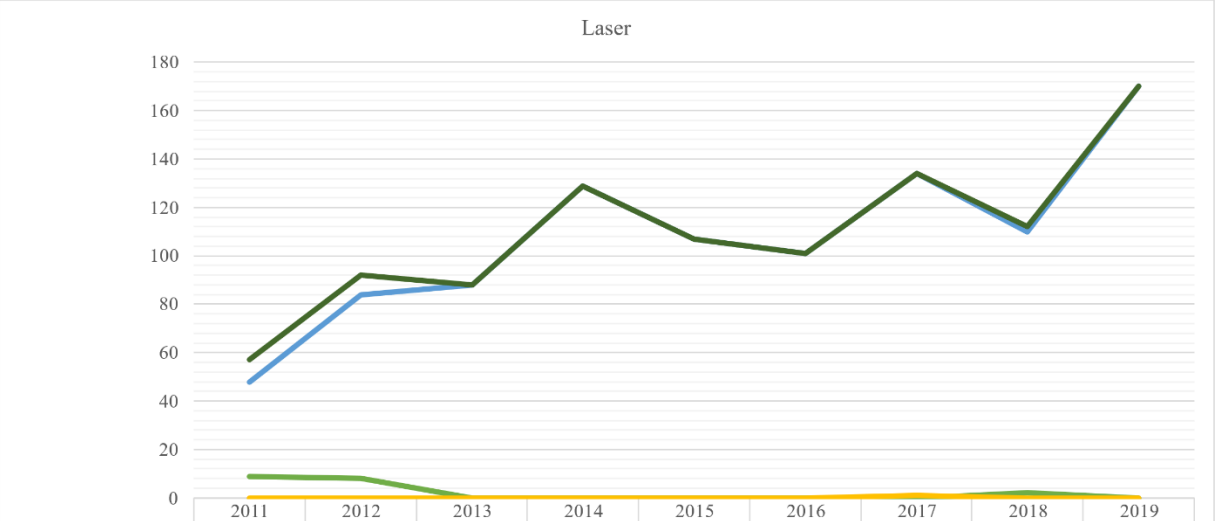
Another of the risks identified is wildlife hazards. These are closely related to the presence of wildlife on the airfield of airports. Collisions of this type also occur at major airports and can adversely affect the safety of passenger operations. During the study period, there were only two accidents correlated with the occurrence of wildlife on the airfield of airports.

Actions taken against risks associated with birds and wildlife include the development of a manual describing the methodology of risk management of aircraft collisions with birds and other animals at airports in FIR (Polish Flight Information Region) Warsaw. The goal of the effort is to maintain zero accidents that could be caused by the presence of animals.

Unmanned aerial vehicle (drone) operations are another hazard. They are one of the newest threats to civil aviation safety. UAVs appear in spaces above airports. Irresponsible behavior by drone owners stems from a lack of required licensing and adequate knowledge of airspace regulations. In 2019, the first accident involving the described hazard occurred, and the number has been increasing dramatically since then.

In 2011, there were six such events and incidents, and in 2015, there were already 18. In 2018, there were already 57 events and incidents, and as many as 75 events and inidents and one accident in 2019. Actions taken against this hazard include the continuation of the "Use your head when flying" information and education campaign aimed at the UAV industry and the planned introduction of a pilot program to deploy drone flight ban signs in specific zones. The objective of the actions taken was set to monitor UAV events to determine the actual threat level.

Blinding pilots with lights from the ground (lasers) was identified as another hazard. This hazard comes from deliberate violations of standards and regulations by third parties. The scale of the phenomenon is constantly growing, so it was decided to take preventive measures against it. There were numerous events and incidents caused by laser use during the study period (Figure 6).



	2011	2012	2013	2014	2015	2016	2017	2018	2019
Event	9	8	0	0	0	0	0	2	0
Incident	48	84	88	129	107	101	134	110	170
Undefined	0	0	0	0	0	0	1	0	0
Event+Incident	57	92	88	129	107	101	134	112	170

Figure 6. The number of LASER events in air traffic from 2011 to 2019. The author's own elaboration based on: Civil Aviation Authority (2020). National Safety Plan 2020-2023. Appendix to the National Civil Aviation Safety Program.

Actions against this threat include controlling the number of events based on the data collected and drafting a LASER information and education campaign that can be conducted in schools. The purpose of this effort is to continue to monitor events and verify the extent of the problem related to blinding pilots with lights from the ground. Adequately effective preventive measures (information campaign) should also be selected.

Aviation events involving glider towing also constitute a group of hazards. These are indicated as those that may be directly related to equipment that is not subject to aviation certification: winches and tow ropes. In contrast to others, this group is characterized by a high number of accidents (an average of about four accidents per year) and at the same time a low number of incidents and events (an average of about eight cases per year). This may indicate a lack of reporting on this group of hazards.

Actions taken against this threat include, for example, controlling the number of events and verifying whether additional measures are needed to address the quality of the equipment used to tow gliders. This is also expected to reduce the number of accidents in this event category.

The next hazard is the performance of flight operations below acceptable visibility. It is associated with landing operations below the Runway Visual Range (RVR) minima, which can result in very serious aviation accidents. There are regular attempts to continue such operations despite having knowledge about RVR below the minimum value. Thus, it is important to determine whether this is incidental or whether these actions are related to intentional unwarranted risk-taking. There were no accidents in the described hazard category, and the number of events and incidents did not reach more than 13 (in 2012) during the period under study, which is an average of six per year.

Risk mitigation activities associated with this hazard focus on, among others, controlling the number of events in this category, with the goal of determining the true magnitude of events associated with landing operations below the minimum RVR.

Events involving the transportation of hazardous materials also pose significant risks, as such transportation is only safe if specific regulatory restrictions are followed. Any failure to comply with the regulations and neglect of their requirements can contribute to an aviation accident. Hazardous materials incidents are defined as events, other than accidents, involving and relating to the transportation of hazardous materials that result in injury to persons or damage to property or the environment. The number of events related to the transportation of hazardous materials is increasing annually, but no accidents or serious incidents occurred during the study period. There was only an average of about 39 incidents and 170 events per year.

The largest increase in the number of events and incidents occurred between 2017 and 2018 – from 175 to 437 (of which there were as many as 391 events). For this threat, the actions taken include controlling the number of events, analyzing events involving the transportation of lithium batteries, or measuring the level of culture of reporting events of this type by the responsible parties. The objectives of the efforts are to continually observe and minimize events involving the transportation of hazardous materials.

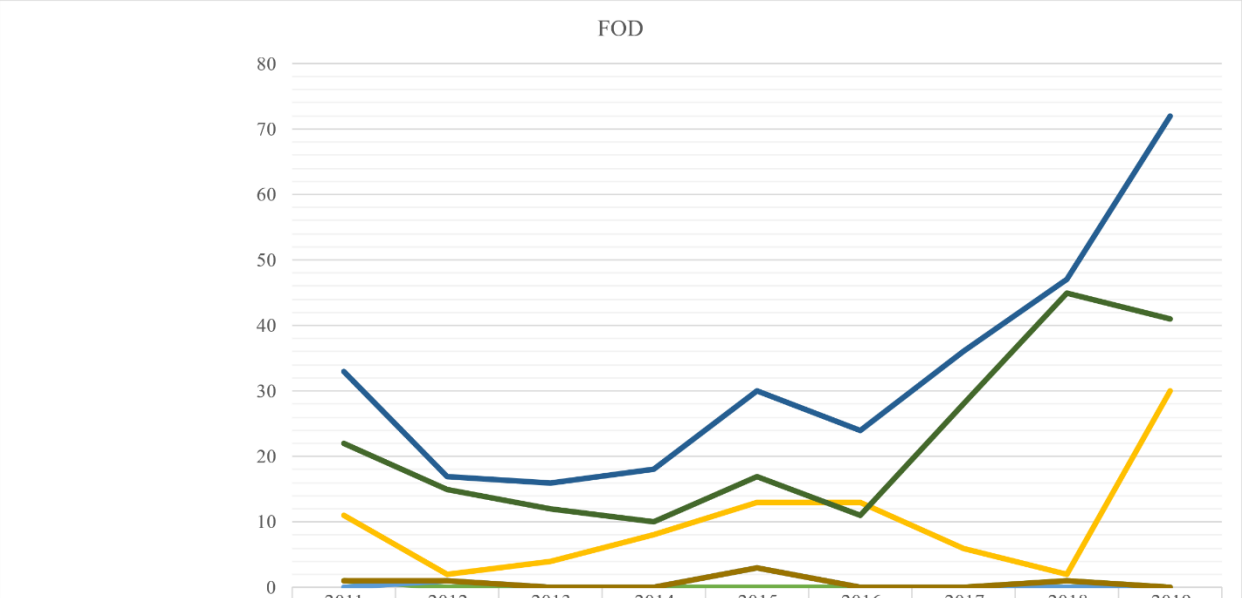
Helicopter events also pose a threat to air traffic. They are singled out due to the specificity of helicopter operations. This group was required to be monitored by the President of the Civil Aviation Authority.

Accidents related to helicopter events associated with SCF-NP (System/Component Failure or Malfunction (Non-Powerplant)) occurred in 2013 and 2019 (single cases). In contrast, the number of events and incidents increased from 13 in 2011 to 25 in 2015. In 2016, there was a significant increase in recorded events and incidents, amounting to 49 cases. A year later, that number had risen again to 68. In 2018, there was a decrease to 55 events and incidents, but in 2019, the number increased again to 61.

Accidents and serious incidents involving SCF-PP (System/Component Failure or Malfunction (Powerplant)) on helicopters occurred with high frequency. Twelve such situations occurred during the study period.

Helicopter event risk minimization measures focus on, among others, analyzing accidents and serious incidents, as well as controlling events. Their goal is to verify the number of events against all aviation events.

The last group of hazards are FOD (foreign object damage) events. These can have effects both on the ground and in the airspace. FOD is divided into those found on runways, taxiways, and aprons and those associated with aircraft maintenance (Maintenance FOD). FOD events are increasingly being reported in civil aviation, as it is clearly shown in Figure 7.



	2011	2012	2013	2014	2015	2016	2017	2018	2019
Accident	1	0	0	0	0	0	0	1	0
Serious incident	0	1	0	0	3	0	0	0	0
Incident	11	2	4	8	13	13	6	2	30
Event	22	15	12	10	17	11	28	45	41
Incident+Event+Undefined	33	17	16	18	30	24	36	47	72
Accident+Serious incident	1	1	0	0	3	0	0	1	0

Figure 7. The number of FOD events in air traffic from 2011 to 2019. The author's own elaboration based on: Civil Aviation Authority (2020). National Safety Plan 2020-2023. Appendix to the National Civil Aviation Safety Program.

Preventive actions against this type of hazard include, but are not limited to, analyzing accidents and serious incidents to verify the number of events involving foreign objects at airports and during the maintenance process.

5. Discussion of the study results

The conducted analysis shows that the highest average value of accidents and serious incidents is characterized by the category of events related to glider towing (Fig. 8). In 2015, there were 12 such cases (maximum). Many accidents and serious incidents are also associ-

ated with SCF-PP and foreign object damage (FOD). Hazards such as RVR, hazardous materials events, birdstrike, and laser blinding of pilots did not result in accidents or serious incidents over the study period. All of the average numbers of accidents and serious incidents in the assigned hazard categories are shown in the bar graph (Fig. 8).

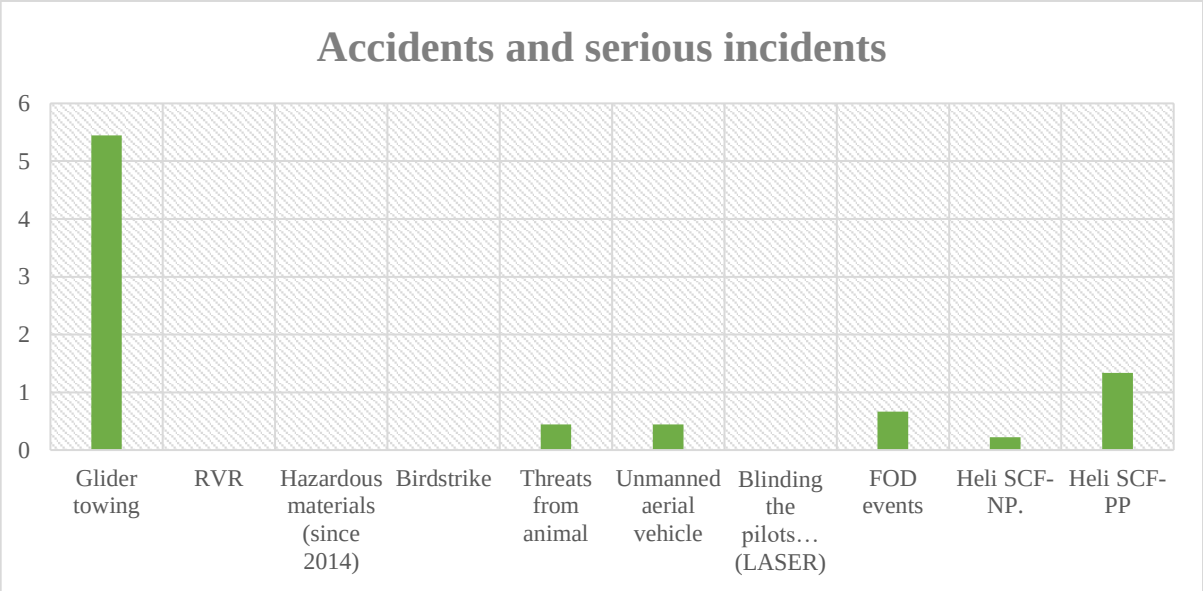


Figure 8. The average number of accidents and serious incidents in the provided air traffic hazard categories from 2011 to 2019. The author's own elaboration based on: Civil Aviation Authority (2020). National Safety Plan 2020-2023. Appendix to the National Civil Aviation Safety Program.

Similarly, the average number of incidents and events related to the types of hazards for Polish civil aviation was analyzed (Fig. 9).

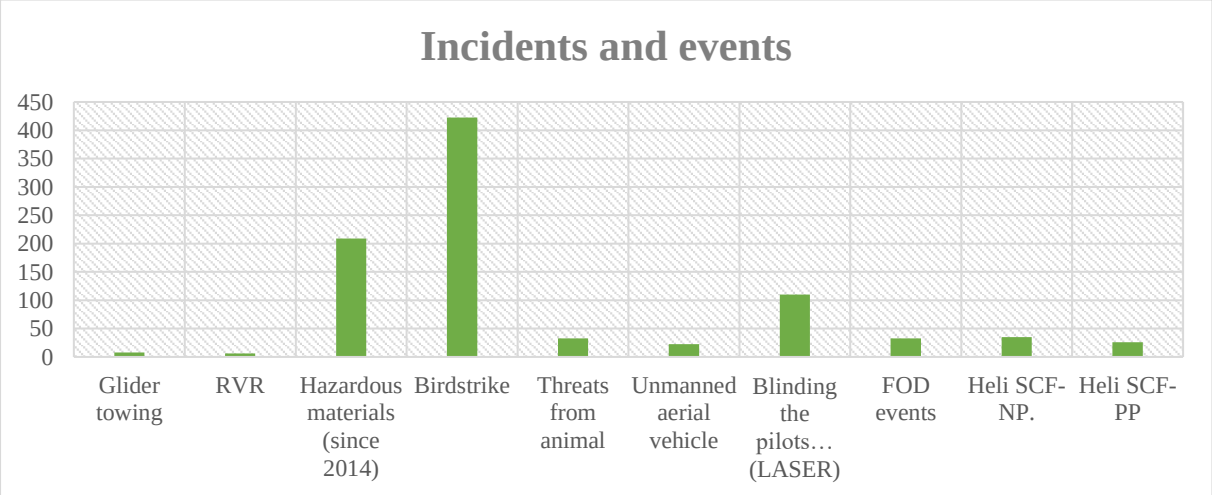


Figure 9. The average number of incidents and events in the provided air traffic hazard categories from 2011 to 2019. The author's own elaboration based on: Civil Aviation Authority (2020). National Safety Plan 2020-2023. Appendix to the National Civil Aviation Safety Program.

The “Birdstrike” hazard group definitely stands out. Incidents and hazards in this category were recorded, on average, 426 times per year. Situations, where hazards may have been caused by improper transportation of hazardous materials, were also common, with an average of 209 times per year (data spanning from 2014 through 2019). The number of events and incidents is also high for the use of lasers to blind pilots; such an attempt to disrupt flight safety has been made on average 110 times per year. Interestingly, each of these hazard categories simultaneously has zero accidents and serious incidents over the 2011-2019 period. The least number of events and incidents are characterized by events related to glider towing and attempted landings in limited visibility. No accidents occurred as a result of attempting to land when the RVR minimum was not met; however, hazards associated with the glider towing process caused an average of 5 accidents and serious incidents per year in civil aviation over the study period.

6. Summary

Safety is inherent in all modes of transportation, not just aviation (Borucka & Pyza, 2021; Kamiński et al., 2016; Świderski, 2009). The article was created in order to identify the hazards in Polish civil aviation and the scale of the danger they are associated with. Moreover, the hazards that are characterized by the highest frequency were indicated. This allowed for the identification of incidents that should be subject to the procedure of special analyzes and supervision. Moreover, such a survey provides information on the level of security on a national scale. It enables the planning of precise preventive actions. It allows for more effective use of available funds and resources, both on the part of aviation entities and the state budget. It is also part of the risk management strategy. The analysis was based on data collected in the National Safety Plan 2020-2023. This study uses figures for accidents, serious incidents, incidents and events for the period 2011-2019 (only such data was made available to the authors).

Extremely dangerous events are linked to the actions of third parties. The increasing number of events related to the mishandling of UAVs is a major concern for air traffic safety. This may have to do, for example, with the uncomplicated process of purchasing an unmanned aerial vehicle and its growing popularity. The steps taken against this threat are primarily preventive in nature (education and information campaign, decision to place information signs). In addition, laser blinding of pilots is also a hazard with tragic consequences. In this case, it was also decided to conduct an awareness campaign about the harmfulness of this type of activity.

The study shows that over the period under review, the number of safety incidents and events in civil aviation has been steadily increasing. This implies the need to undertake scientific research in this area as well as to develop tools and methods to prevent such events (Boyd, 2017). This study is an introduction to such analyses and may be expanded by conducting further research covering a broader time horizon. Conducting an analysis of hazards that occurred in 2020 (COVID-19 virus pandemic outbreak) would certainly identify areas that threatened flight safety even with air transport restrictions. In addition, mathematical modeling methods may be used to identify and forecast in this area. It is also possible to extend the analysis to other areas of aviation.

Declaration of interest – The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this article.

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