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Analysis of past aircraft incidents in respect of occurrence of aircraft accident

Keywords

aviation incident, aviation safety, aviation accident, aviation accident investigation

Abstract

Aviation safety is the science and practice of risk management in aviation. It includes the prevention of aviation accidents and incidents through research, education of aviation personnel, passengers and the general public, and the design of aircraft and aviation infrastructure. The aviation industry is subject to considerable regulation and supervision. Despite this, aviation incidents continually occur. Most of these are of low consequence and involve only the loss of money or the temporary frightening of the crew and bystanders. Unfortunately, there are also accidents in which people die, and this loss is already unimaginably high. The chapter covers topics that include an analysis of aviation incidents, comparing the type of incident, the causes of the incident and the consequences the incident has caused. Also the models of safety management in aviation are presented and compared, so that the number of unsafe situations can be significantly reduced.

1. Introduction

Maintaining aviation safety is essential to avoid dangerous incidents that lead to loss of life, health and property. Aviation has a significant impact on our society. According to numerous studies, flying is the safest way to travel and, in addition, it can carry people over enormous distances in a relatively short time (Klich, 2011).

The International Civil Aviation Organization (ICAO) expects all Member Countries to prioritise and continue to implement the standards set by ICAO, which are linked to the safety objectives and priorities of the Global Aviation Safety Plan (GASP). Despite the numerous solutions, standards, rules and procedures that have been established, dangerous situations continue to occur in airspace that involve real threats to our lives (Grzejda, 2014).

The scope of the contribution would include the investigation of approximately fifty hazardous events, including tragic incidents where people have died (Babiarz, 2015). From each situation (incident, serious incident and accident), information will be extracted about: time of day, phase of flight, causes, aircraft damage, occurrence location and about recommendations of the National Commission for Aviation Accident Investigation (Vintr & Valis, 2006).

The main research problem was to find the best comparison so that the results obtained do not

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present a distorted overview of reality. In addition, the chapter presents the factors affecting the level of aviation safety and how it is managed (Valis et al., 2019).

2. Classification of aviation incidents

When embarking on an analysis of aviation incidents, it is first necessary to clarify what an aviation incident is. What makes it different from an aviation accident and what features they have in common (Kołowrocki & Kuligowska, 2018). The legislator resolves these differences by creating in Poland the Aviation Law of 3 July 2002. Based on it, it states that: *an aircraft accident means an occurrence associated with the operation of an aircraft which has taken place from the moment when any person has boarded the aircraft with the intention of flying until all persons on board have disembarked from the aircraft and during which any person has suffered at least serious injury, or the aircraft has been damaged or its structure has been destroyed, or the aircraft has been lost and not found and an official search for it has been cancelled, or the aircraft is in a place to which access is not possible* (ISAP, 2007).

It should be mentioned, however, that an air accident is not a situation where the damage to the aircraft did not cause a threat to health or life. Often, committees investigating an aviation event consider that since the crew was not injured and the aircraft was damaged, there is no indication that the event should be described as an aviation accident (Compa, 2019).

In this case, it is used the term aviation incident understood as any situation related to the operation of an aircraft that could or had a negative impact on the safety of the operation and is not an aviation accident, i.e. no injury occurred during the incident. In addition, the term serious aviation incident appears in the Act as an incident in which there was hardly an aviation accident.

2.1. Types of aviation incidents

Despite a huge number of interventions on many different areas (production, support systems, procedures, legislation), accidents and unsafe incidents in aviation still occur. One may feel that everything has been done in terms of safety, and it turns out that it is still not enough. In addition, it is doubtful whether a state can ever be reached where there are no disasters in the skies. Since aviation incidents are occurring and will unfortunately continue to occur in the future, they must be categorised and analysed.

Different types of divisions of unsafe states in aviation can be found.

According to the European Organisation for the Safety of Air Navigation (Eurocontrol), the best division is to distinguish the following states:

- accident as an event related to the operation of an aircraft (during which a person is injured or the aircraft is damaged),
- major incident as an event bordering on an accident (e.g. a significant breach of separation between aircraft without control of the situation),
- major incident as events likely to cause an accident (e.g. significant separation failure but with control of the situation),
- significant incident as events significant controller/crew workload, failure of technical systems (e.g. aircraft communications) but without safety impact (ISAP, 2002).

On the other hand, the aforementioned Polish law since 2002 provides three categories of events, they are:

- aircraft accident as an event associated with the operation of an aircraft during which any person sustains any serious injury or the aircraft is damaged,
- serious aircraft incident as an incident whose circumstances indicate that an aircraft accident almost occurred' (ISAP, 2002) (e.g. damage to an aircraft or significant breach of separation between aircraft without control of the situation),
- aircraft incident – an occurrence associated with the operation of an aircraft, other than an aircraft accident, which has or could have had an adverse effect on safety.

Research is still ongoing as to which allocation model is most authoritative and which of these is most likely to reduce these incidents. These are not the only apportionment options that are used worldwide, but they are the most popular.

2.2. Research areas

In accordance with Regulation No 376/2014 of the European Parliament and of the European Council of 3 April 2014 on notification and analysis of occurrences in civil aviation and their subsequent actions, an obligation has been imposed on institutions to collect reports on hazardous situations in aviation. It applies to both mandatory and voluntary reporting of these incidents.

To improve the possibility of data exchange between these organizations nationally and internationally, the regulation introduced a standardized event classification. This allows the data to be directly forwarded to the European Coordination Centre for Aviation Incident Reporting Systems (ECCAIRS).

The Regulation takes into account the classification developed by ICAO, the Accident/Incident Data Reporting (ADREP) systematics (Dąbrowska & Soszyńska-Budny, 2018). According to it, the areas mentioned below should be taken into account when analyzing the incident (ULC, 2017).

Airport – events that occurred at the airport, taking into account its layout and airport services. No aircraft need be involved in this situation. It is sufficient if there are negligence and issues regarding the certification of the airports or the failure to maintain the runway properly, such as an un-snowed runway or incorrectly marked taxiways.

Abrupt manoeuvre – this category includes situations involving deliberate manoeuvring of the aircraft to ensure safety and avoid an accident (e.g. avoiding an obstacle), as well as sudden braking on the ground during taxiing.

Incorrect contact with runway – applies to all situations where the take-off or landing was incorrect (including hard landings, landing too long, crossing the centre line, etc.).

ATM/CNS – this category includes incidents related to Air Traffic Management (ATM) and Communication, Navigation and Surveillance Services (CNS). It includes any failure of Air Traffic Control (ATC) systems and problems of control service personnel.

Bird strike – any possible (potential or real) contact with birds during flight, taxiing, take-off or landing.

Cabin safety events – this category includes incidents related to Air Traffic Management (ATM) and Communication, Navigation and Surveillance (CNS) services. It includes any failure of ATC systems and problems of control service personnel.

Controlled flight towards ground – events of unsafe approach of the aircraft with terrain, water or an obstacle. This does not include situations that occurred during taxiing. This includes in this category both situations during Instrument Meteorological Conditions (IMC) and Visual Meteorological Conditions (VMC). An example would be a circumstance where the pilot has lost spatial orientation and, having full control of the aircraft, is guiding it towards the ground.

Collision with obstacle(s) during take-off/landing – this category includes collisions with obstacles of which the pilot was aware or should have been aware – obstacles marked on aviation maps or described in the Aeronautical Information Publication (AIP).

Evacuation – this category includes all circumstances that occur during evacuation from an aircraft. They may include: an improper evacuation attempt or incorrect operation of evacuation equipment.

Hovering events – it applies only to incidents involving aircraft overhead transport. In practice, these are situations in which a helicopter will be a participant, as it is on these aircraft that all tasks involving overhead transport are performed.

Fire/smoke (non-collision) – the appearance of fire or smoke not resulting from an aircraft collision. This would include a fire caused by the malfunction of on-board equipment or ignition of a fire by persons inside or outside the aircraft.

Fire/smoke (as a result of collision) – this category includes fires that result from aircraft collisions during flight, taxiing, landing or take-off.

Fuel-related – in this category, there will be aircraft incidents that occurred through lack of fuel or interruption of fuel supply to the power unit, but also occurred due to icing of the carburettor or the use of fuel not intended for this type of engine. If, during the flight, there was a very high risk of running out of fuel, but the engines were not ultimately shut down, such an event should also be included in this category.

Ground collisions – any situation that occurred during taxiing and resulted in the aircraft colliding with another aircraft or obstacle.

Glider retrieval incidents – hazardous situations that caused an aircraft incident or accident and those that were close to causing an incident. They include all situations related to the towing of gliders by aircraft and the retrieval of gliders by airport winches (fixed and mobile). Examples include rope entanglement, loss of control or even inappropriate unhooking of the glider during climbing flight (Rządkowski et al., 2021).

Ice – this category includes the adverse effects of snow, ice or freezing rain on the aircraft surface, understood as a decrease in the performance of the propulsion unit, a reduction in the control of the aircraft through loss of controllability or glazing affecting the field of vision.

Loss of control – on the ground – all situations that occurred on the ground, including the initial take-off phase or the final landing phase.

Loss of control – in flight – this category will include, by analogy, situations that occurred in the time after the aircraft detached from the runway until the aircraft touched the runway. These will be events whose primary cause was loss of control of the aircraft, including lack of control during autorotation (Grzejda, 2021).

Loss of lift in flight – this category is for gliders, paragliders, balloons and dirigibles only. During the flight of the above-mentioned aircraft, a forced landing must occur in adventurous terrain, resulting from loss of static, atmospheric (thermal, gravity, mountain) lift.

Dangerous approach/collision in flight – this is a very broad group of events covering all collisions between two aircraft in flight. It includes situations resulting from pilot error, but also from air traffic controller error.

Medical – events involving the occurrence of an illness or injury to a person on board an aircraft. This includes crew as well as passengers. They may originate in turbulence, storm, but also as a result of intentional actions (e.g. an act of aggression) or the most common situations, i.e. injuries resulting from movement on board or attempted boarding (disembarkation).

Navigational error – this includes incidents resulting from an error in navigation that occurred on the ground or in the air. Malfunctions related both to pilot error (e.g. misreading of parameters), but also to malfunctions of navigational aids, which would result in the aircraft being incorrectly positioned during taxiing or on an erroneous flight course.

Ground handling – this category combines hazardous and dangerous incidents arising from the incorrect actions of ground staff. It does not apply to the action of the pilot, but only to persons working at the airport, during activities such as loading and unloading the aircraft, boarding, refuelling, de-icing, pushback, towing and handling the aircraft during parking.

Runway departure – any action (intentional or accidental) that resulted in an aircraft being off the runway. Applies only to the take-off and landing phase, and does not include falling off the runway during taxiing.

Runway incursion – all situations in which the pilot's runway operations are disturbed by the abnormal presence of another vessel or vehicle, as well as other persons in the vicinity of the runway. This includes the presence of land animals as well as air animals (birds).

Runway incursion – other – unexpected encounter with animals or action taken by the pilot to avoid a collision on the runway. This section also includes uncontrolled airports.

Runway incursion by vehicle, aircraft or person – unexpected events resulting in a collision or risk of such a collision and any evasive action taken by the crew.

System/sub-assembly failure or malfunction (non power) – all failures and malfunctions of aircraft systems excluding engine failure. This category also includes failures that did not result in an accident or aircraft incident, but only forced additional action by the crew. Examples are system software failures and component malfunctions observed during technical inspections.

Failure or malfunction of the power unit – this will include damage and malfunctions of aircraft engines, preventing the flight from taking place as previously planned. The operation of the engines understood as the operation of the propulsion unit itself, but also the operation of the propeller, propeller shaft, gearbox, tail rotor.

Security related – actions by others (persons other than the crew) which were of a criminal or unprocedural nature and which resulted in an aircraft accident or incident.

Turbulence – in this group, events will be found that hindered or interrupted the flight and their source was the appearance of turbulence. It could have been caused by a mountain wave, a storm cloud, an aerodynamic trace and a wind dodge.

Unintended flight into IMC – this group applies when a pilot, while flying other than Instrument Meteorological Conditions (IMC), finds himself or herself in a situation that forces him or her to fly by instrument. Whether or not the pilot has a rating for such flight. The relevant fact is that such a flight was unintentional. In addition, the condition of the aircraft (the presence or absence of equipment allowing such a flight) is an important element.

Premature/delayed touchdown – incidents where the pilot performing the landing did not take the correct descent path and placed the aircraft in a position where touchdown occurred before the runway threshold or the aircraft came to a stop behind the runway end line (Giel & Plewa, 2016).

Collision with wildlife – any action performed by the pilot to avoid contact with wildlife on the ground. This includes the taxiing phase, pushback, the initial part of the take-off, but also the final part of the landing (including touchdown and braking).

Wind or storm surge – dangerous situations caused by the occurrence of thunderstorms, strong winds, lightning, heavy rain, which resulted in the necessary intervention of the pilot and his action to reduce the effects of the aforementioned events or the pilot's actions contributing to escaping contact with the atmospheric phenomena. This does not include icing of the aircraft or the occurrence of turbulence (Kołowrocki et al., 2017).

Other – all other occurrences not categorised above but relevant to the safe conduct of flight operations (Mogilski et al., 2020).

Unknown or unspecified – a category which includes cases such as:

- missing aircraft,
- lack of aircraft data to assign the event to another category,
- a clear indication that no additional information about the event will be available.

2.3. Causes of incidents and accidents

Aviation safety experts have realized a while ago that aircraft incidents and accidents almost always result from a series of events, each involving one or more causal factors. Thus, the cause of an accident or incident has many facets. These events can be reviewed as links in a chain (National Research Council, 1998).

Analyses of accident event chains are generally only useful for preventing similar accidents. Because there are so few accidents relative to the number of flights, the focus of safety programs on accidents alone affects only a small proportion of potential accidents and is reactive rather than proactive. A proactive approach, which can eliminate hazards before they cause accidents, requires effective methods of tracking chains of events both for incidents as well as accidents. Preventive action (rather than just corrective action) can then be taken – based on the recurrence rate of the various links in the chain and their potential to contribute to future incidents and accidents.

Identifying the exact causal factors for each event can be complex, requiring good judgement and accurate interpretation of the facts. There may be more than one causal factor for each event, and some factors naturally overlap.

Combinations of factors and cascading cause-effect sequences need to be carefully examined to understand all causal factors. For example, to prevent accidents caused by a system failure, the system that failed can be modified to prevent similar failures in the future (Gołda & Zieja, 2014). In addition, understanding whether the failure was caused by the failure of another system, improper maintenance, an abnormal operating environment, etc., can suggest additional corrective actions (Maturo & Hoskova-Mayerova, 2019).

An accident prevention strategy that considers all causal factors associated with incidents and accidents - not just primary factors - has greater potential to prevent accidents by eliminating factors that are common to many incidents and accidents. These common factors serve as *traps* that may be easier to identify and eliminate than the unique, extremely rare factor that may be called the *root cause* of a particular accident. For example, if a series of accidents appears unrelated, corrective action may focus on the specific circumstances of each accident. However, a comprehensive review may reveal an underlying flaw, such as poor pilot training, safety management or aircraft maintenance that is common to the entire accident series.

3. Coincidence (relatedness) of incident and (in relation to) air accident

The State Air Accident Investigation Committee is required by law to publish the final report after the investigation of an air accident to the public. In addition, such a document is sent to the Civil Aviation Authority and the organization which

was responsible for the respective flight. Nearly sixty reports, including incidents, serious incidents and accidents, were selected for analysis from all those created by the commission over the last three years, counting the date of publication and not the date of the event.
The events selected for analysis were those that occurred at or in close proximity to the airport (Figure 1).

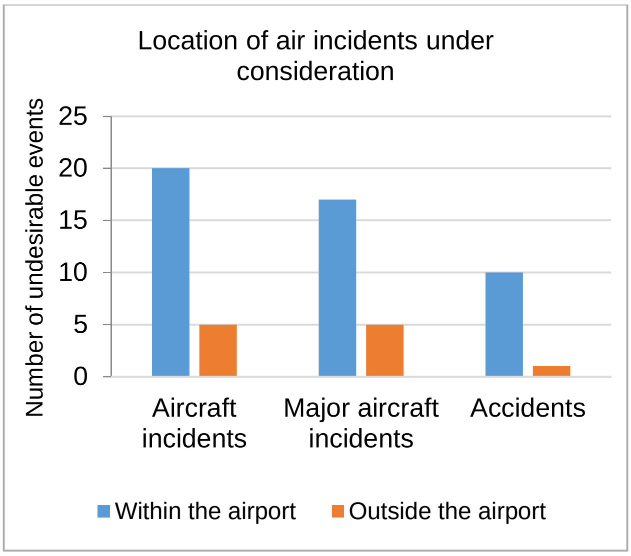

Figure 1. Graph representing the location of incidents.

Most unsafe situations occur during approach and circle flight, where there is a concentration of aircraft (Figure 1). This problem does not apply to flights at controlled airports, where all aircraft must declare their intention to arrive and enter the airport zone. This prevents aircraft from accidentally approaching each other in the air. Incidents also occur in large numbers during the touchdown and run-in itself, where the wrong moment of alignment and angle of descent causes damage to the landing gear.
In the majority of incidents, the ships' crews were experienced or very experienced. There were few incidents resulting from pilot errors during the beginning of flight training. This fact may be surprising but it confirms the theory that the young student pilot is fully concentrated and does not succumb to the effect of routine, which proves to be disastrous (Figure 2). In addition, the student pilot is controlled by the instructor which increases the level of safety. It can be concluded that the training system is set up correctly and its functioning is achieving the intended results.

The aforementioned routine, may lead to a reduced concentration of attention by the pilot. Feeling very confident, the pilot stops observing the instrument indications as well as the situation around the aircraft. In addition, an experienced pilot, aware of his or her high skills, will more often attempt manoeuvres that require a high degree of precision. It is then easy to turn safe flight into daring aircraft control.

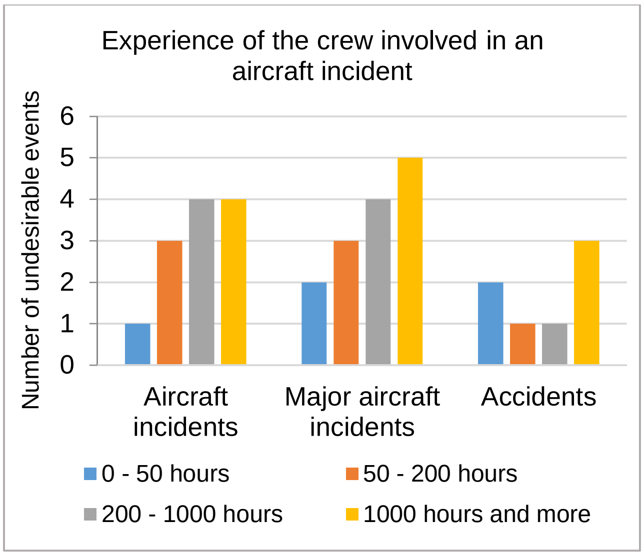

Figure 2. Crew experience graph.

Another element occurring during the event that was analysed is the phase of flight (Figure 3).

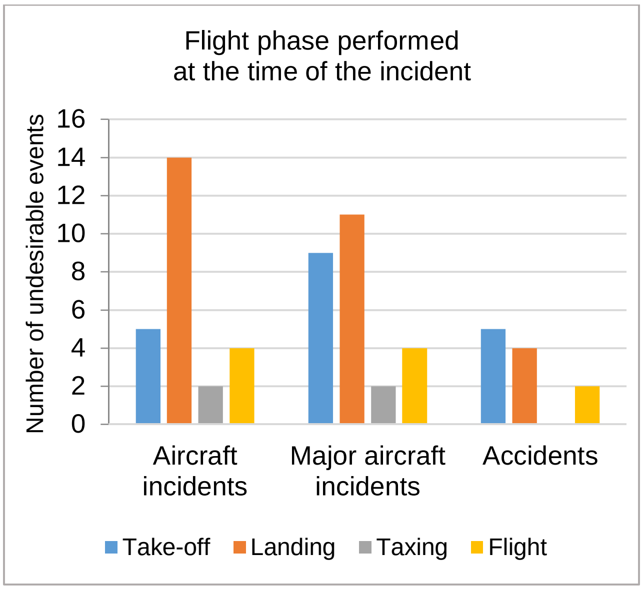

Figure 3. Graph representing the phase of flight at the time of the incident.

Most hazardous situations occur at the moment of performing a take-off or landing. In the landing stage, not only the moment of the touchdown itself was included, but also the entire landing approach process. The circuit flight was included in both take-off and landing. During the flight (en-route flight), the percentage of incidents is not significant, confirming that this stage of flight is the safest.

3.1. Assessment of probability of occurrence of aircraft accident

An air accident is the same as the occurrence of casualties or injury to those involved in the incident. There are mainly two types of condition in the situations analysed (Hasilova & Valis, 2018). The first is the dangerous approach of two aircraft in the air, but without the occurrence of damage to the components of these machines (Giel et al., 2017). The second condition, on the other hand, is the contact of an aircraft with the ground in an unexpected manner, resulting in damage (Kuben et al., 2019):

- fuselage,
- the wing structure,
- landing gear,
- rotor blades
- or aircraft engine blades.

Incidents occurring in the air (lack of adequate separation), have no consequences, i.e. no persons or property were injured. However, if contact had already taken place between aircraft, the consequences would have been tragic, and therefore there would be an aircraft accident. In the analyzed cases, the distances between the aircraft ranged from 50 meters to 150 meters. The assessment of the distance is a subjective assessment by the crew, as there were no distance meters installed on board these aircraft to unambiguously determine the actual distance from the aircraft. Taking into account that, on average, aircraft collisions occur once a year in Poland, especially during the approach phase or entry into the circle above the airport, it should be considered that the probability of an air accident for the discussed incidents is high. The pilots involved in these incidents may not even have a sense of how close they were to a crash. In the air, the perception of space is different, due to the lack of nearby reference points.

A characteristic group of incidents are situations in which damage is done to the aircraft, but the crew is not injured. In these cases, the pilots experience a sense of fear and the threat of death. Despite the presence of stress and the desire to survive, the probability of changing into an aircraft accident is not so high. A much *safer* option may be landing gear failure rather than a mid-air collision with the opposition. Of course, when the aircraft is brought into an unfavourable configuration for the pilot, there is a risk of, for example, breaking an arm or hitting the cabin elements with the head, which will result in the event being reclassified, but nevertheless the lives of the pilot and crew will not be as at risk as in the earlier situation.

A significant proportion of the causes of incidents are based on a lack of proper concentration and disregard for the constant observation of instrument readings and the area around the aircraft. It can be concluded that recklessness as well as the routine of experienced flight personnel and their taking *shortcuts* contribute to this.

Another large group of causes is the failure to maintain separation when entering the overflight circle and entering the zone without permission.

The next set of causes are technical defects in equipment, systems or individual aircraft components that forced the crew to make an emergency landing, or these defects were noticed during routine checks.

The least numerous group are the reasons due to lack of experience (Figure 4).

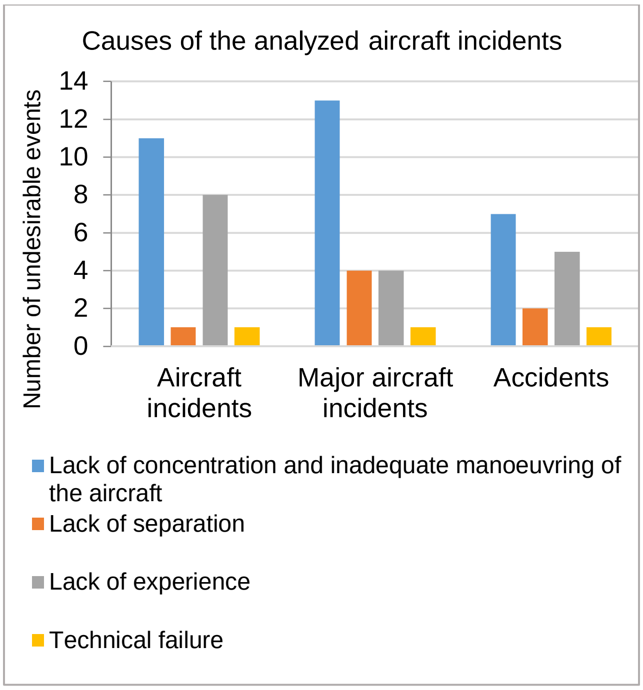

Figure 4. Graph showing the causes of the analyzed incidents.

However, in each of the figures presented (Figures 1–4), the most important feature stands out, from the point of view of the subject of the work as well as its purpose. Regardless of the classification of the aviation event, its cause, the phase of flight, the experience of the crew is proportional. The predominant events are those occurring on or within an airport, the crew is made up of experienced persons, usually performing a take-off or landing manoeuvre. The conclusion to be drawn from this observation is that the causes and other circumstances of an aviation incident (including a serious incident) are very similar to those of an aviation accident. It should therefore be considered that the probability of an aviation incident *turning* into an accident is very high.

4. Conclusion

Aviation is an exciting part of the world and many lives are enthralled by it. Unfortunately, it also has its dark side, which is unexpected events, incidents and accidents. The entire aviation industry relentlessly tries to do its best to ensure that no more tragic situations happen. History teaches us, however, that we can never achieve such a perfect level of safety. An analysis of the incidents that have taken place in Poland in recent years clearly shows that the human factor has the most important role in this process. Constant attempts to find a procedure to eliminate this factor do not yield satisfactory results. Obviously, the number of tragic incidents has been significantly reduced thanks to the procedures, standards and laws developed. One of the most important elements of aviation safety management is the collection of data on all dangerous and even worrying situations. For this reason, the number of recorded aviation incidents itself has increased significantly. One might conclude that aviation is becoming more dangerous, but nothing could be further from the truth. Until a few years ago, there was not such a well-developed *management culture* and simply certain incidents were not recorded anywhere which made it impossible to analyse them properly.

With knowledge of a greater number of dangerous situations or deficiencies, it is easier to develop new recommendations adapted to a changing world. It is therefore disturbing that, despite the reliable reporting of air accidents and the subsequent analysis by the State Commission on Aircraft Accidents Investigation (SCAAI), which determines the causes of the situation, in only five out of fifty-nine cases did the commission make recommendations with the following wording:

- State Commission on Aircraft Accidents Investigation (SCAAI) recommends that the airport operator should proceed to conduct a risk assessment of the number of simultaneous flight operations permitted in the area of Warsaw-Babice Airport (EPBC) (PKBWL, 2023),
- discuss the incident with the pilot (PKBWL, 2023),
- in the Commission's view, a better solution than executing a glide would have been to go to the second aero-circle under the circumstances (PKBWL, 2023).

The line between an incident and an accident is very thin. Sometimes all it requires is one small, additional factor to turn a dangerous situation into a tragedy. In addition, an incident can leave permanent damage to a pilot's mental health. It is not always possible to notice this change immediately, and this would already be a premise for classifying such an incident as an accident. The cases analysed also convey an optimistic message: the mistakes that were made in these cases could usually be described as *minor*. It takes so little behind it to eliminate this nuance and make a safe flight without the risk of loss of life.

This analysis may have shortcomings in the disparity between incidents and aircraft accidents.

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