IDENTIFICATION OF THREATS AND RISK ASSESSMENT IN AIR TRANSPORT WITH THE USE OF SELECTED MODELS AND METHODS

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Abstract

Air transportation is one of the safest means of transport, but carrying out activities in the area of aviation incident analysis still remains necessary. Proper assessment and analyses of incidents must be based on identification of hazards in the area. Safety hazards can occur in the airspace, on the airport premises, and in the area of aircraft ground handling. The development of unmanned aircraft is also associated with the emergence of further safety hazards. Therefore, it is of great importance that available methods and tools be used to assess risks in each area. To this end, there are a lot of available quantitative and qualitative methods for analysing air transport incidents. An important aspect is the analysis of aviation incidents, which can contribute to proactive measures aimed at improving air transport safety. The paper presents selected aviation incident analysis methods and risk assessment tools.

Keywords: risk of hazards management, remotely piloted aircraft system, hazard sources

1. Introduction

Safety in air transport is one of the most critical elements and is considered a foundation for any aviation operation's performance. The National Civil Aviation Safety Program is implemented to achieve a high level of safety. It is a set of regulations aimed at improving safety, serving to integrate activities at the state level regarding policies, legal aspects, and goals in this area. Despite certain events that limit the development of civil aviation (such as the pandemic and the war in Ukraine), the dynamism characteristic to the development of this branch

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of transport is noticeable, and that continues to necessitate the introduction of specific solutions to minimize the number of occurring threats that constitute the emergence of incidents and aviation accidents.

The causes of aviation accidents can vary and can result from the failure of technical systems, the human factor, and management of air traffic. In many cases, aviation activities are identified with aircraft moving through the airspace and personnel working on board. Innovative solutions for air traffic management, such as Virtual Remote Towers, are also important in air traffic, which cause further safety risks. It should be noted that air traffic is also an operation involving the ground handling of aircraft, maintenance of aircraft, and handling of passengers and their luggage, but it can also be related to other means of transportation, such as unmanned aircraft. The field of unmanned aircraft (UAV) is developing extremely rapidly in terms of technology and applications for various functions, widely used in the service sector, but safety remains the most important issue. Polish and Community aviation legislation applies to and regulates the rules pertaining to flights and the areas where it can be performed. This does not change the fact that every flight involves the risk of an event that may prove to be dangerous to human health and life, as well as an aviation incident or accident.

Threats may occur within any of these activities that can lead to an aviation incident or accident. Safety management for any area of aviation operations involves the identification of threats and then taking appropriate action. Depending on whether we are talking about anticipating possible threats stemming from system imperfections or actual adverse events that have occurred, these actions can be preventive or corrective.

As practice indicates, official investigations of aviation incidents are now geared toward qualitative analysis. Given the decreasing number of accidents, it appears that the historically basic source of information for the safety assurance system is becoming insufficient (Skorupski, 2018). This gives rise to the need of paying attention to events with less severe consequences, i.e., major aviation incidents. Quantitative analysis of accidents is extremely difficult despite the many methods that can be used in this area. Various types of analyses and methods are used to achieve a sufficiently high level of safety (Janic, 2000).

Risk analysis in aviation operations is a process directed at reducing the consequences arising from the occurrence of a hazardous event, incident or aviation accident. The safety of aviation operations is considered in a wide spectrum of issues and has been present in the literature for many years. It depends on several factors that are now receiving special attention, including the competence and qualification of aviation personnel (also analysing the area of aircraft ground handling) (Skorupski, Grabarek, Kwasiborska, Czyżo, 2020), the impact of meteorological conditions and familiarity with procedures and their correct application.

There has been a lot of literature on runway safety. This area has been analysed extensively because of the potentially severe consequences of an air traffic accident

(Meyer & Tarnai, 2015; Stroeve et al., 2013). Many research papers include risk analysis issues concerning air traffic procedures in the airport area but also during the operation of equipment and systems in this area (Schönefeld & Möller, 2012; Siergiejczyk et al., 2014). The proactive approach is important from a risk analysis perspective and is linked to ICAO assumptions. One incident investigation method is the simulation-based assessment of the probability of an incident turning into an accident. Petri nets are one convenient tool for studying traffic processes in different transport modes (Skorupski, 2013; Tang et al., 2016). Other examples of methods used in this area are the Event Tree Method with Fuzzy Probabilities (ETFP) (Lower et al., 2016), Functional Resonance Analysis Method FRAM (Patriarca et al., 2017; Studic et al., 2017) or Human Factors Analysis and Classification System HFACS (Ergai et al., 2016; Uğurlu et al., 2018).

This paper presents several methods described in the literature and used to identify threats with an example applied to the selected area. It also presents the essence of threat identification and later on characterizes the selected methods along with their application to various areas of aviation operations.

2. Threat identification and risk management

A threat is defined as a possibility, event, circumstance, existing or potential condition/situation conducive to injury, human illness or death, damage to or loss of a system, equipment, or property, or environmental damage, incident, or accident. Risk is a combination of the probability or frequency of a threat and the amount of damage that the fulfilment of the threat brings. There is a difference between the concept of threat and the concept of risk. Risk means the result of threats and is a calculable value. A threat that is a source of potential harm does not imply the fulfilment of harm (Kwasiborska, Stelmach, 2016).

Aircraft event causality models SHEL-L, J. Reason or other quality tools, including Ishikawa Diagram, can be used to identify threats (Chądzyńska, Klimecka-Tatar, 2017). A qualitative tool, the Ishikawa diagram, allows the determination of the degree of importance of the causes and a comprehensive assessment of the threat under study.

Figure 1 shows an example of the use of an Ishikawa diagram, which is a cause-and-effect diagram leading to the collapse of a UAV.

The result of the incident was the fall of the UAV, while the left side of the diagram shows the causes leading to the incident. The diagram shows a graphical analysis of the impact of various factors and their interrelationships, causing a specific qualitative problem. Risk determines the actual possibilities of the consequences of the threat that occurred. The risk assessment algorithm is shown in Figure 2.

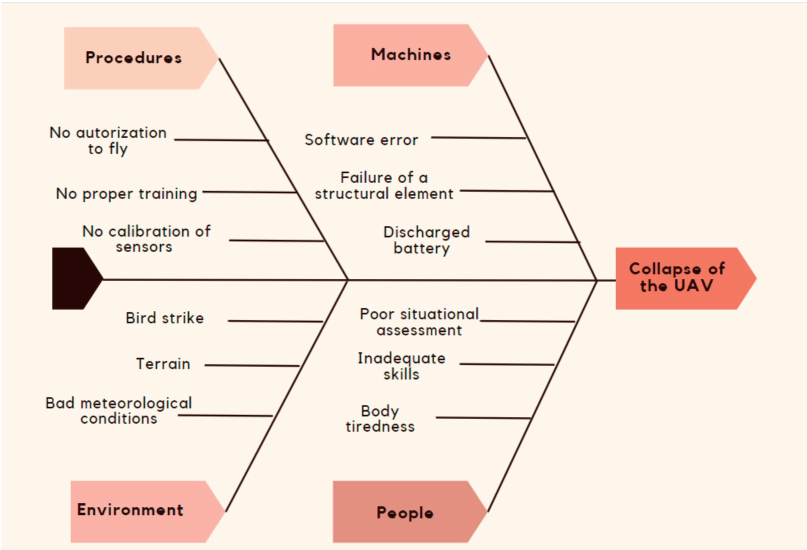

Figure 1. The example of the Ishikawa diagram pertaining to factors that lead to the collapse of a UAV

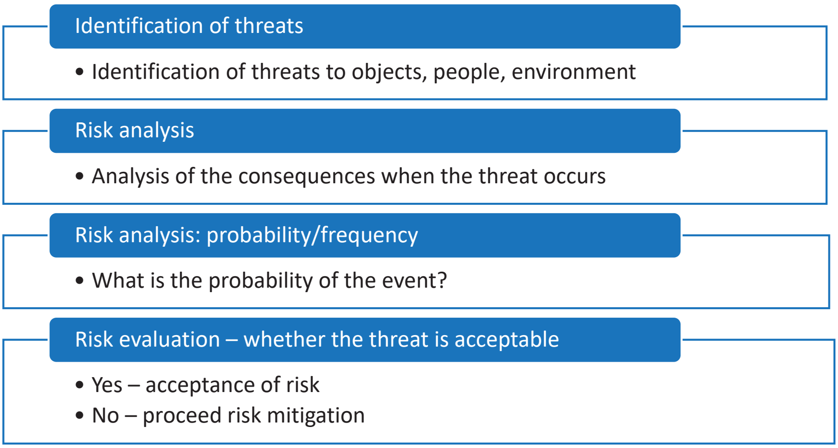

Figure 2. The risk assessment algorithm

Sources: study based on Safety Management System

Safety risk management is a much more complex concept that involves identifying aviation safety threats. In the next step, the probable effects of the identified threats are assessed in terms of importance and the possibility of their occurrence. The estimation of the level of risk determines the introduction of corrective actions, protective measures to minimize the emergence of risk, or the monitoring of the results obtained (Doc 9858, 2018). Risk assessment is carried out starting with establishing the roles and areas of responsibility of the entities and individuals involved in the process. The proper selection of methods and tools necessary for risk assessment is particularly important at this point. The next step is to determine the scope of the risk assessment and present the tasks and problems to be solved.

It is also important to indicate the types of threat identification (Wyszywacz, 2021):
1. reactive – analysis of past events or their effects (results from security incident investigation) - of little use due to lack of data;
2. proactive – actively looking for threats within the existing processes;
3. predictive – collecting and analysing data to identify possible negative impacts or events in the future, analysing processes and the environment to identify potential future threats and initiating mitigation actions.

Identification of threats can involve many areas (Wyszywacz, 2021):
1. human factor – physiological, psychological and cognitive characteristics of people involved in air transportation activities;
2. operational procedures and practices – preparation of documentation, procedures and instructions for operational needs in the analysed area;
3. technical factors – bugs in the software, technical failures, mechanical damage to components, radio interference;
4. organizational factors – recruitment, training, resource allocation, supervision;
5. environmental factors – meteorological, navigational, technical parameters.

Risk assessment is an important element in the preparation and decision-making processes related to the execution of flight operations. Obtaining a reliable and credible assessment is possible with an appropriate risk assessment method. A prerequisite for accurately assessing threats is also the selection of a method, appropriate to the problem posed and related to the specific circumstances.

3. Methods and tools to assess risk

Many documents (manuals, standards, guidelines) address the issue of risk assessment in aviation, among which the ICAO Safety Management Manual Doc 9859 is of key importance (Doc 9858, 2018). The method described in the Manual is based on a matrix on which risk is valued qualitatively (probability is not mathematically defined). Assessment of the level of risk is made by comparing two parameters: the probability of occurrence of an event and the severity of consequences as follows:

$$W = P \times S$$

where:

W – risk index,

P – the probability of occurrence of an event, understood as the chance/possibility of occurrence of the causes of the threat,

S – the severity of consequences.

The security management handbook specifies the risk management process model based on risk analysis. Each identified threat is assigned an estimated probability (Table 1) and risk severity (Table 2) on a five-level scale.

Table 1. Probabilities of safety risks

Value	Probability	ICAO description	FAA ARP
1	Extremely improbable	Almost inconceivable that the event will occur	Expected to occur < every 100 years
2	Improbable	Very unlikely to occur	Expected to occur once every 10-100 years or 25 milion departures, whichever occurs sooner
3	Remote	Inlikely to occur, but possible	Expected to occur about once every year or 2.5 milion departures, whichever occurs sooner
4	Occasional	Likely to occur sometimes	Expected to occur about once every month or 250,000 departures, whichever occurs sooner
5	Frequent	Likely to occur many times	Expected to occur more than once per week or every 2500 departures, whichever occurs sooner

Source: study based on Doc 9858.

Table 2. The severity of safety risks

Value	Severity	ICAO description	FAA ARP
A	Catastrophic	Equipment destroyed Multiple deaths	Complete loss of aircraft and/or facilities or fatal injury in passenger(s)/worker(s); or Complete unplanned airport closure and destruction of critical facilities; or Airport facilities and equipment destroyed
B	Hazardous	A large reduction in safety margins, physical distress or a workload such that the operators cannot be relied upon to perform their tasks accurately or completely Serious injury Major equipment damage	Severe damage to aircraft and/or serious injury to passenger(s)/worker(s); or Complete unplanned airport closure, or Major unplanned operations limitations, or Major airport damage to equipment and facilities
C	Major	A significant reduction in safety margins, a reduction in the ability if the operators to cope with adverse operating conditions as a result of an increase in workload or as a result of conditions imparing their efficiency Serious incident Injury to persons	Major damage to aircraft and/or minor injury to passenger(s), or Major unplanned disruption to airport operations, or Serious incident, or Reduction on the airport`s ability to deal with adverse conditions
D	Minor	Nuisance Operating limitations Use of emergency procedures Minor incident	Minimal damage to aircraft, or Minor injury to passengers, or Minimal unplanned airport operations limitations, or Minor incydent involving the use of airport procedures
E	Negligible	Few consequenses	No damage to aircraft but minimal injury or discomfort or little risk to passenger(s) or workers

Source: study based on Doc 9858

Table 3 shows the matrix that represents the evaluation of the level of risk, defining three levels of risk tolerance (acceptance): unacceptable risk marked in red, tolerable risk marked in yellow and accepted risk marked in green. The main disadvantage of risk analysis using the matrix method is its subjective nature, allowing everyone to create risk acceptance levels and estimate parameter values and thus a specific event.

Table 3. Safety risk assessment matrix

Risk probability	Risk severity				
	Catastrophic A	Hazardous B	Major C	Minor D	Negligible E
Frequent 5	5A	5B	5C	5D	5E
Occasional 4	4A	4B	4C	4D	4E
Remote 3	3A	3B	3C	3D	3E
Improbable 2	2A	2B	2C	2D	2E
Extremely improbable 1	1A	1B	1C	1D	1E

Source: (Doc 9858, 2018)

One of the tools used to analyse and assess risk is the Risk Analysis Tool (RAT) (Eurocontrol, 2023). It is a methodology used to classify safety events in air traffic management and consistently and comprehensively identify risk elements. It also allows users to effectively prioritize the selection of actions intended to reduce the impact caused by these events/elements.

The tool analyses two types of events - operational events, i.e. those related to the proper application and execution of procedures, and events related to the technical side of air navigation services. In the case of operational events, risk exposure is analysed taking into account the severity of the event and the recurrence or likelihood that the event will occur again. The severity of the event is defined as the risk of collision (the separation achieved and the bluntness of its change) and the amount of control the controller had to exercise during the event. For back-end events, the event's severity and recurrence are determined by a combination of criteria. These criteria are mapped in an overview table (being the core of this methodology), which allows defining the safety risk caused by a combination of back-office errors.

The result of the incident assessment obtained using the RAT methodology provides information about the risks present in connection with an incident in the ATM system, both in its ground part (ATC Center) and in the whole system considered globally (air and ground parts and crew participation). With the help of the RAT tool, it is possible to analyse risks in different areas of aviation operations (Table 4).

Table 4. Types of scoring mark sheets

Number of aircraft involved	Purpose
More than one aircraft	When 2 or more aircraft are involved in the occurrence – usually for incidents with airborne aircraft.
Aircraft – aircraft tower	When the occurrence is an encounter between two aircraft under tower control. This includes situations where: a) Both aircraft are airborne, b) Both aircraft are on the ground, c) One aircraft is airborne and one aircraft is on the ground.
Aircraft with ground movement	When the occurrence is an encounter between aircraft and a vehicle, excluding a situation when the vehicle is occupying/intersecting an active runway. In this scenario, the aircraft could either be on the ground or airborne.
One aircraft	When only one aircraft is involved occurrence.
ATM specific occurrence	To be applied in the case of technical occurrences affecting one`s capability to provide safe ATM services.

Source: study based on Risk Analysis Tool – Guidance material, Eurocontrol

The example aviation incident (Figure 3) involved an unsafe situation between an aircraft in take-off and an aircraft approaching landing.

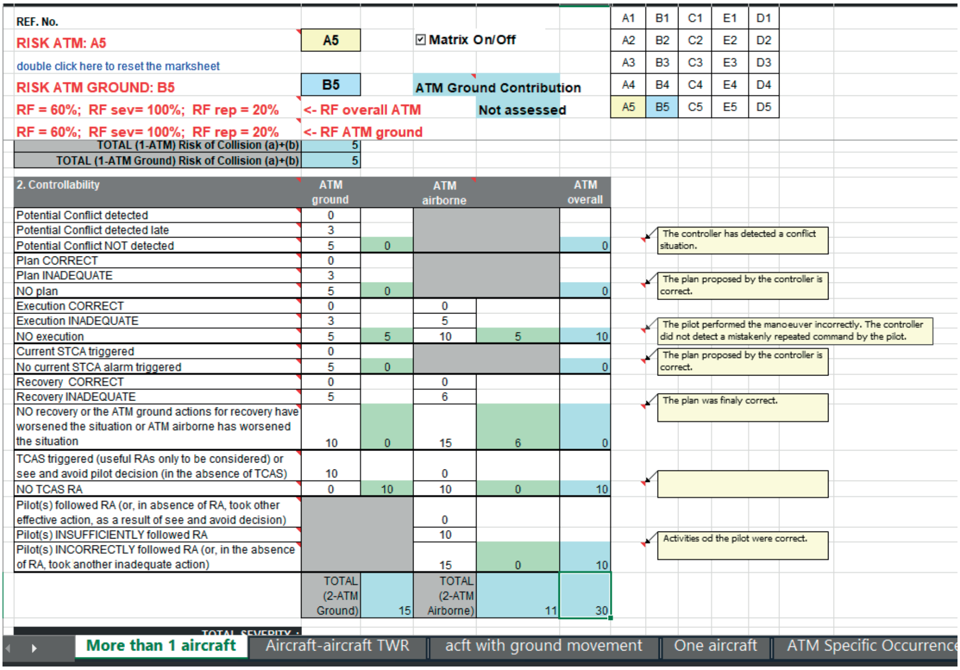

Figure 3. Example of analysis incident using RAT

Source: elaboration based on RAT

The results obtained can be interpreted based on the risk matrix. The Reliability Factor FR measures the level of confidence in the assessment made in the worksheet based on the data available to answer the questions in the said worksheet. In the example, the FR is 60%, which means that the results are not fully reliable, due to insufficient data to answer the questions.

The risk matrix shows that for ATM GROUND risk is A5, meaning extremely rare but with very serious consequences. For ATM GROUND is B5, which means that the event is extremely rare with serious consequences.

4. Bow Tie method

The Bow Tie method, otherwise known as the fly method, is used to schematically analyse the potential for the development of risks arising from the occurrence of an adverse event. It considers causes, effects, and barriers preventing the development and reducing these risks, illustrating this in a simple diagram.

The Bow Tie method was developed in 1979, and it allows graphical presentation (in the form of a diagram) of the dependence of the impact of the causes, creating threats on their effects. The first step is to define the threat in diagrams central part. The left side of the diagram contains the causes (events leading to the threat) and the barriers that let or stop them from causing the threat. The right side of the diagram identifies possible scenarios for the consequences of a given threat and further barriers that reduce the severity of those consequences. The Bow Tie method uses, in part, event and fault tree methods.

The Bow Tie method makes it possible to illustrate the entire cause-effect network in an uncomplicated way, along with its possible limitations. As a result, it is possible to understand how the UAV went down and what preventive measures should be taken to prevent it from happening in the future (Figure 4). In addition, unlike the matrix method, it allows analysing cases with multiple causes and different levels of impact.

According to the results of the Bow Tie risk analysis, although most of the failures were related to the machine itself, the group of experts and operators considered putting more emphasis on the quality of practical and theoretical training as suggestions for reducing the causes of UAV falls. They also felt that examinations should be performed in a more meticulous way, which would help reveal any gaps and errors in teaching. While the level of training and examinations can be increased, there is a lack of appropriate tools and methods to reduce the likelihood of a UAV breaking in flight. It is possible to use better parts and materials, but this would only marginally increase the level of safety. The main reason for this is the lack of equipment redundancy and the serial reliability structure. If the number of components were to be doubled, each UAV would have a large mass and large dimensions. The method makes it possible to show the entire cause-and-effect network in an uncomplicated way, along with the possibilities of constraints. As an effect, it is possible to understand how the UAV collapsed and what preventive measures should be taken to prevent a similar fail from happening in the future. In addition, unlike the matrix method, it makes it possible to analyse cases with multiple causes and different levels of impact.

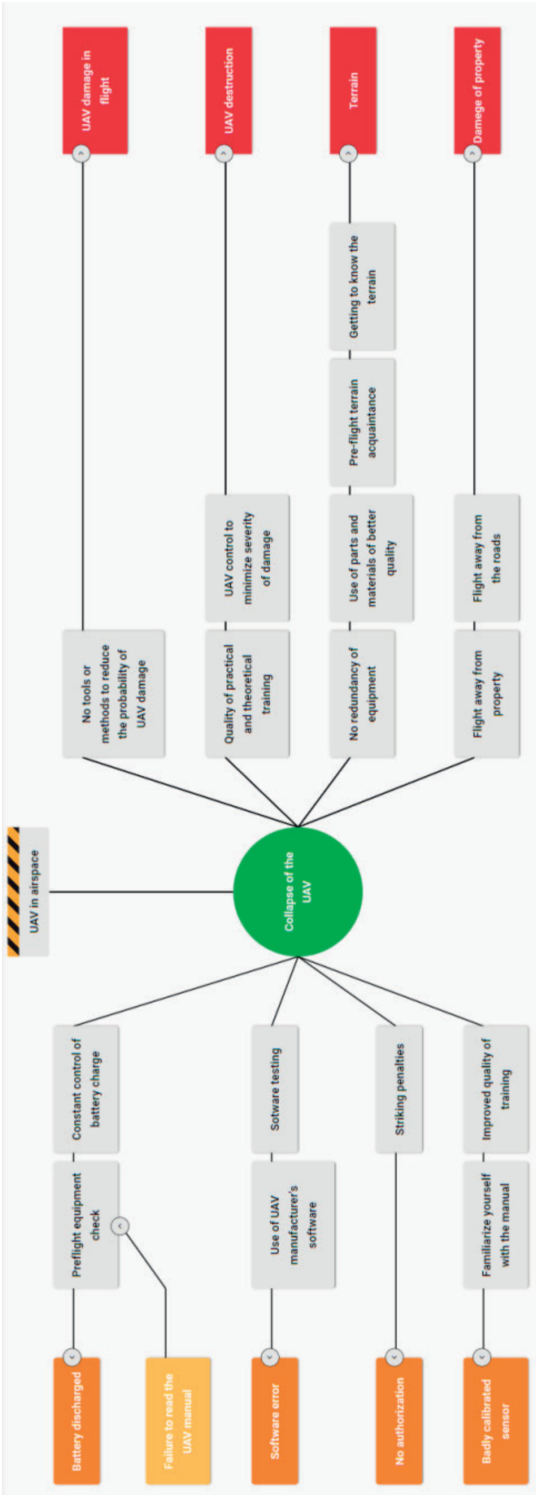

Figure 4. The example of Bow Tie diagram concerning the collapse of a UAV

5. Event Tree Analysis method

The Event Tree Analysis (ETA) method is based on the analysis of sequences of events that may follow a single initiating crash (Skorupski, 2015). The ETA method starts with an event that may occur and then leads to an intermediate effect that may also occur and lead to a more serious effect. Each event is evaluated according to only two states: success or failure. The method uses inductive thinking, in which the course of the analysed situation is described from the initial initiating event. Probable intermediate events up to the final events are predicted as consequences of the initiating event. The method can be applied to the risk analysis of any technical system, including air traffic management systems. Interesting results can be obtained by combining event tree methods with the fault tree method. The method is easy to apply and allows taking into account both technical and human factors, as well as the environment, as long as it is possible to assume that they are two-state objects – either they work correctly or they do not.

The graphical ETA model, developed in a binary fashion, shows cause-and-effect relationships, with the top branch indicating successes and the bottom branch indicating failures. ETA allows creating a picture of the course of the analysed process from the cause to the final threat and determining its level. ETA can also be used to describe the process quantitatively. The probability of the final event is calculated as the product of the probabilities of all preceding events.

An example of application of the ETA method is the risk analysis of the introduction of the Remote Tower system. A Remote Tower is a system of cameras and sensors installed at an airport, usually with low traffic, to replace a traditional airport control tower. Information from the cameras, radars and sensors is sent via appropriate transmission channels to the Remote Tower Center, where controllers can control take-off and landing operations at several airports. This generates savings so that airports with less traffic can operate profitably. The Remote Tower system performs exactly the same functions as a traditional airport control tower, the only difference being the way they are performed. With both solutions, i.e. the traditional and remote towers, the most important issue is to provide visual observation of the airport's runways, taxiways and manoeuvring areas. Such a solution can generate many safety threats.

According to a document issued by the Civil Aviation Authority (Guidance, 2010), it is assumed that for problems of a technical nature, a negative effect can happen with a probability of p=0.1 and the absence of this effect with a probability of p=0.9. On the other hand, human error is assumed with a probability for both success and failure of p=0.5.

An incident involving the failure of a camera transmitting video from the airport to the air traffic controller was analysed. The lack of image transmission from the Runway RWY does not allow noticing the presence of a vehicle on the RWY (Figure 5).

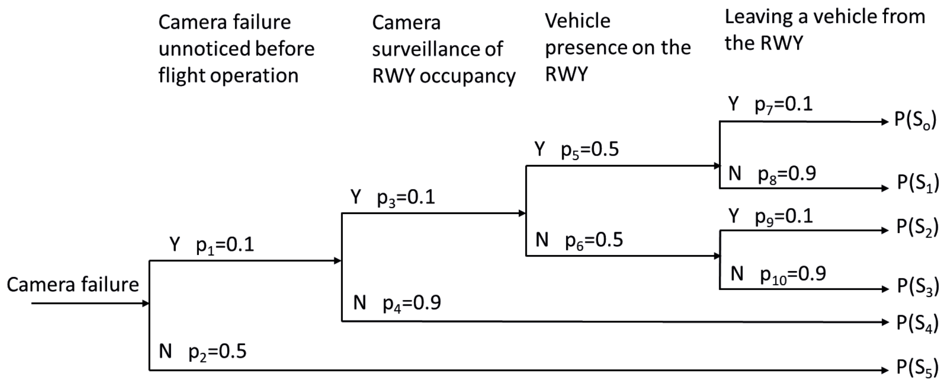

Figure 5. The example of ETA about camera failure

The impact weights have been established for the presented event and are shown in Table 5. To calculate the risk of the analysed event, the total inability to perform take-off/landing operations on the runway was assumed, i.e. a weight value of 3.

Table 5. The example of weight

Weight	Description
1	Delays of air operation
2	Blocking of the RWY
3	Unable to execute flight operations

The estimation of the risk of an aviation incident is based on the formula:

$$R = P(S_i)*w \quad \text{for } i=1,\ldots,5$$

where:
$P(S_i)$ – the probability of an event
w – severity of the effect of the event/incident

Examples of the probabilities of the analysed event are included below.

$$P(S_0)= p1*p3*p5*p7=0.0025$$
$$P(S_2)= p1*p3*p6*p9=0.5*0.1*0.5*0.1= 0.0075$$
$$P(S_3)=p1*p3*p6*p10=0.5*0.1*0.5*0.9= 0.0225$$

Assuming the highest weighting of 3 for the scenario, since the feasible real consequences are the possibility of causing a collision with another vehicle on the runway, it would additionally block the road preventing other vessels from performing operations on it.

The risk of the scenarios is:

$$R(S_0)= P(S_0)*w11 =0.0025*3=0.0075$$
$$R(S_2)=P(S_2)*w11=0.0075*3=0.0225$$
$$R(S_3)=P(S_2)*w11=0.0225*3=0.0675$$

The estimated risk has an approximate value and is not an accurate reflection of the actual value. In estimating the risk, probabilities were adopted in accordance with data published in a document issued by the Civil Aviation Authority entitled "Guidance on the Conduct of Hazard Identification, Risk Assessment and the Production of Safety Case". In order to obtain more authoritative results, it is necessary to carry out tests for each of the situations mentioned, based on which it would be possible to determine unequivocally what probability could be assigned to them.

6. Event tree with fuzzy probabilities method ETFP

Analysing the causes of an actual airport incident and identifying the possibility of it turning into an accident can be done using the event tree method with fuzzy probabilities (ETFP). This enables looking for the weakest elements of the safety assurance system that need to be strengthened so that they continue to serve as safety barriers. It is necessary to take into account the premises that favour the occurrence of an accident, both related to human factors and traffic conditions. The method analyses event trees with fuzzy probabilities, and its general algorithm is as follows:

1. Selection of the incident and assumptions of the analysis with the moment in time when the analysis begins.
2. Identifying factors affecting the possibility that an incident could be transformed into an accident need to be defined.
3. Construction of classic event trees covering all cases of continuation of movements by participants of the incident.
4. Identifying collision scenarios and determining general formulas for the probability of each continuation scenario.
5. Estimation of probabilities of premises using linguistic variables that define the probabilities of their occurrence.
6. Calculation of the fuzzy probability of an accident.

An example for the application of this method can be found in the 2016 aviation incident at the Warsaw Chopin Airport. This incident involved a Ground Support Equipment unit (GSE-ST tractor and stairs) and a pushed Airbus 320 aircraft, for which the GSE tractor (GSE-PB) was responsible. While pushing the aircraft out of the parking area, the GSE-ST moved behind the aircraft, which led to the aircraft's emergency stop. The aircraft had its anti-collision lights on and the GSE-PB tractor had its warning lights on. The basic rule of vehicle traffic on the airport's manoeuvring area is to give way to aircraft while they are performing landing, taxiing or take-off operations. The cause was a failure to exercise due diligence and to comply with the applicable airport traffic rules. Two event trees were developed using the classic ETA method (Figure 6). The first was for GSE-ST traffic continuation, while the second was for GSE-PB traffic continuation.

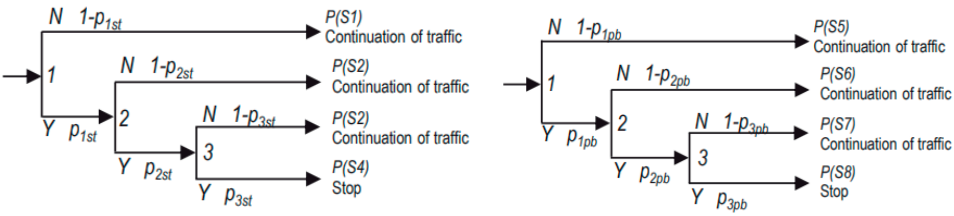

Figure 6. The example using ETPF for GSE-ST and GSE-PB

Source: (Kozłowski, Kwasiborska, Rutkowska, Skorupski, Stelmach, 2019).

The authors presented the fuzzy probabilities of each continuation scenario and the ultimate probability of the incident turning into an accident (Table 6).

Table 6. Fuzzy probabilities of collision scenarios

Scenario	*m*	*n*	*p*	*q*	Linguistic value
S1	-4.1	-3.1	-2.1	-1.1	*big*
S2	-6	-5	-4	-3	*average*
S3	-3.1	-3.1	-3.1	-3.1	*big*
S4	-4.1	-2.1	-2.1	-1.1	*big*
S5	-6	-4	-4	-3	*average*
S6	-1.2	-1.1	-1.1	-1.1	*very big*
Accident	-5.3	-3.1	-3.1	-1.9	*average/big*

Source: (Kozłowski, Kwasiborska, Rutkowska, Skorupski, Stelmach, 2019)

The authors (Kozłowski, Kwasiborska, Rutkowska, Skorupski, Stelmach, 2019) have analysed the relationship between the level of training of Ground Support Equipment (GSE) operators and the probability of an incident turning into an accident. Experiments were performed confirming this relationship, which can be important for planning individual training programs tailored to specific GSE operators. The authors presented conclusions indicating that the method and results can be used to analyse the probability of an event turning into an accident.

7. Conclusions

The paper characterizes selected risk analysis methods and safety assessment tools. Examples of the application of the mentioned risk analysis methods are also presented. Investigation of aviation incidents is one of the most important activities to improve air transport safety. The task is difficult and involves determining the course of the event. Analytical methods are primarily based on data and statistics that relate to the occurrence of analogous events in the past, similar conditions, analogous equipment, similar behaviour of aviation personnel and the organization of the tasks performed. Using quantitative methods to analyse aviation incidents is difficult because of the human factor involved. People continue to play a significant role in air transportation.

The basis of a properly performed risk analysis is the identification of threats in various areas of air transport. The methods presented for air transport are based on threat identification and a reactive approach to safety management. Most of the methods are characterized by the occurrence of a chain of activities, including: identification of threats, estimation of the probability of realistic threats, the extent of consequences (severity), evaluation of risks and, possibly, methods of dealing with risks. It is important to go even further in developing methods of risk analysis obtaining a higher level of safety in air transport.

As may be seen, analyses can be carried out using various tools and methods characterized by the subjective feeling of the expert executing such an assessment. Using a minimum of two equivalent analyses by means of different methods will enable a more accurate assessment. Civil aviation authorities usually recommend using the chosen risk assessment method, but other methods should also be verified when analysing air transport safety as a priority.

The purpose of using risk assessment methods is to be proactive, i.e. to prevent aviation incidents. Aviation entities (airport operators, air carriers, air navigation service providers) compile information on potential sources, which is analysed and then preventive or corrective action is taken. In addition, ground handling agents are analysed and evaluated by airlines during preauditing, i.e. before a ground handling agent is selected for the operation of aircraft. Therefore, it is essential to conduct analyses and risk assessments at every stage of aviation activities, both in the air, while moving on the ground and during handling on the ground. Such activities are cognitive and allow establishing the accuracy and effectiveness of the risk assessment models used and to analyse the existing dependencies in systems and subsystems. This allows knowing and identifying vulnerable locations where hazards may occur and to answer the question: how to assess risks in air transport in a comprehensive way.

While extending the existing knowledge in the application of risk assessment methods, it is essential to continue working out new methods, developing assumptions and creating a computer application for risk assessment. Another important aspect is to work on hazard risk management, which would take into consideration the secondary effects of arising hazards (and not merely the primary effects).

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IDENTYFIKACJA ZAGROŻEŃ I OCENA RYZYKA W TRANSPORCIE LOTNICZYM Z WYKORZYSTANIEM WYBRANYCH MODELI I METOD

Abstract

Transport lotniczy należy do najbardziej bezpiecznych środków transportu, ale w dalszym ciągu konieczne jest prowadzenie działań w obszarze analizy zdarzeń lotniczych. Prawidłowa ocena i analiza zdarzeń musi opierać na identyfikacji zagrożeń w danym obszarze. Zagrożenia bezpieczeństwa mogą pojawić się zarówno w przestrzeni powietrznej, na terenie lotniska, ale także w obszarze obsługi naziemnej statków powietrznych. Rozwój bezzałogowych statków powietrznych również związany jest z pojawianiem się zagrożeń bezpieczeństwa. Dlatego ważne jest zastosowanie dostępnych metod i narzędzi oceniających ryzyko w każdym obszarze. W tym celu występuje dużo metod ilościowych i jakościowych analizy zdarzeń w transporcie lotniczym. Ważnym aspektem jest analiza incydentów lotniczych, które mogą przyczynić się do proaktywnych działań zmierzających do poprawy bezpieczeństwa transportu lotniczego. W artykule przedstawiono wybrane metody analizy zdarzeń lotniczych oraz narzędzia służące do oceny ryzyka.

Słowa kluczowe: źródła zagrożeń, ocena ryzyka, zarządzanie ryzykiem zagrożeń