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METHODS FOR RISK ASSESSMENT IN THE AVIATION SAFETY MANAGEMENT SYSTEM

Dmytro Bugaiko, Ramil Mammadov, Khusein Akhmadov. "Methods for assessing risks in the aviation safety management system". *The relevance of the topic is due to the fact that the civil aviation of the Republic of Azerbaijan is intensively implementing the recommendations of the international organization ICAO on the "Theory and Practice of Risk Management" in order to reduce the accident rate in air transport. It is proposed to determine the safety indicators of aviation systems through risk in order to carry out an objective measurement of the level of safety, taking into account many possible risk factors. The problem of risk management currently cannot be solved in an integrated form, since the necessary tools are missing. Therefore, a particular problem is proposed for solution, which consists in risk management exclusively in the field of flight safety. Investigated based on the results of a synthesis of materials from scientific foreign publications on the problems of creating promising flight safety management systems in civil aviation using risk management methods in the sense of ICAO definitions.*

This article also discusses the problem of risk identification, risk definition, many different risk management methods and different principles for their classification. A generalization is made on risk management within the framework of new directions for assessing flight safety, taking into account statistical data and monitoring results in civil aviation (CA).

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***Keywords**:* ICAO, flight safety management system, flight safety, hazard factors, probability, threat, risk, risk management, risk management methodologies, risk magnitude, acceptable risk

Дмитро Бугайко, Раміль Мамедов, Хусейн Ахмадов. "Методи оцінки ризиків у системі управління безпекою польотів". *Актуальність теми обумовлена тим, що цивільна авіація Азербайджанської Республіки інтенсивно впроваджує рекомендації міжнародної організації ІСАО з «Теорії та практики управління ризиками» з метою зниження аварійності на повітряному транспорті. Пропонується визначати показники безпеки авіаційних систем через ризик з метою проведення об'єктивного вимірювання рівня безпеки з урахуванням багатьох можливих факторів ризику. Проблема управління ризиками наразі не може бути вирішена комплексно, оскільки відсутні необхідні інструменти. Тому для вирішення пропонується окрема проблема, яка полягає в управлінні ризиками виключно у сфері безпеки польотів. Досліджено за результатами узагальнення матеріалів наукових закордонних видань з проблем створення перспективних систем управління безпекою польотів у цивільній авіації з використанням методів управління ризиками в розумінні визначень ICAO.*

У цій статті також обговорюється проблема ідентифікації ризику, визначення ризику, багато різних методів управління ризиками та різні принципи їх класифікації. Зроблено узагальнення щодо управління ризиками в рамках нових напрямків оцінки безпеки польотів з урахуванням статистичних даних та результатів моніторингу в цивільній авіації (ЦА).

Ключові слова: ICAO, система управління безпекою польотів, безпека польотів, фактори небезпеки, ймовірність, загроза, ризик, управління ризиками, методології управління ризиками, величина ризику, прийнятний ризик

Introduction. One of the most troubling and paradoxical consequences of globalization has been its impact on risks: while globalization has significant potential to mitigate the impact and reduce the likelihood of some risks - local and global, natural and man-made - it has contributed to the spread and amplification of the impact of other risks . The increasing complexity and interconnection of global supply chains spanning continents and oceans has had many positive consequences, but has also, directly and indirectly, led to a series of events that have resulted in loss of life, environmental degradation and economic hardship.

To everyone's benefit, globalization has also stimulated significant scientific and technological progress, resulting in increased prosperity for society. Such developments, of course, carry their own risks, but they have also provided humanity with the opportunity to better defend against their threats. Risk management tools are widely used in civil aviation and in regulatory development. However, in many cases, regulators, regulated companies and other regulatory stakeholders use different terms and refer to different models when talking about risk and risk management.

Risk is a human instinct for the most intense, varied life, for expanding its limits beyond the existing field of activity and self-preservation. Risk does not exist outside of consciousness and culture. Man created it to adapt to dangers. Risk is considered as a fuzzy measure of acceptable business outcomes. Acceptable can be something that society agrees to or rejects. If a way of life improves the quality of life and the value outweighs the risk, then this way of activity is considered acceptable. "Risk is the possibility that human actions or the results of his activities will lead to consequences that affect human values". Risk is associated with the uncertainty of the outcome of an activity. The manifestation of risk can be deterministic systematic or random stochastic.

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The history of the emergence of the concept of "risk" has been examined in some detail by various authors and their conclusions, as a rule, do not always coincide with each other. The word "risk" has ancient roots - translated from the Old Italian "risicare" means "to dare." The history of the formation of the concept of "risk" is largely connected with a person's attitude towards the future. There are numerous concepts and names of risk: one-dimensional, multidimensional, dependent and independent of humans (natural disaster); individual: motivational, active, passive, voluntary, forced; social: personal, group, business, organizational, deterministic systematic, random stochastic, accepted, acceptable, voluntary, conscious, conscious, controlled, assessed, regulated, controlled, neglected, acceptable, unacceptable, tolerable, residual, processed. The subject of risk is studied in the human sciences, in philosophy, psychology, in technosphere activities, in economics and finance - as an expectation of negative outcomes of activity.

Risk is a multidimensional concept. The same risk may include money, the environment, the lives of people with unclear frequencies of the magnitudes of their manifestation. In simple form, the amount of risk is the total value of the expected outcomes or the expected value of an event or action. The concept of risk is associated with the expectation of negative results from activities: danger, loss, damage, harm, illness, injury, death, accident, catastrophe. The etiology of the term "risk" in the concept space is of unclear origin and makes it difficult to identify the actual subject of risk. Vocabulary and grammatical descriptions provide the following information for understanding risk. Risk, Greek ριζα, riza root, base, foot of the mountain; Spanish risco rock, underwater rock, reef; fr. Ch. risquer to maneuver between rocks, to take risks. In European languages from the 15th century, risicum takes on the legal meaning of "loss", "damage" in maritime trade; Arab. rischio and riezgo "in search of prosperity." According to S.I. Ozhegov, risk is the possibility of danger, failure; act at random, in the hope of a happy outcome; at your own responsibility. Much earlier, the concept of risk was outlined in Arnaud-Nicole's work "Logic or the Art of Thinking," 1662: "The fear of harm must be proportional not only to the severity of the harm, but also to the probability of the event". Let us pay attention to the key words of this description: "event", "harm", "proportionality", "probability". Note that the term "risk" is missing. In general, the origin of the term "risk" according to dictionary descriptions remains unclear. The connection between the concept of risk and damage expectations is also unclear.

The challenge of risk identification is the following: a) unclear definition of the term "risk", b) incoherence of alternative risk classification in various subject areas, c) the need to substantiate the risk paradigm, d) the need to substantiate the definition of risk through uncertainty, d) the need to substantiate the definition of risk as negative consequences through a combination of chances and consequences, f) the need to substantiate the paradigm of risk management and/or regulation.

Definition of risk: Risk (R) in this work defines a set of measures for monitoring randomness and a measure of measuring the outcome of events that ensures activity in a given environment and environment.

$$R = H \cdot Ex \qquad (1)$$

H - randomness hazard,
Ex – consequences (exodus).

The fundamental differences between this definition and existing normative descriptions of risk are the following replacements of concepts: a) measures of

randomness of an event (instead of probability), revealed in the choice of fuzzy measures: likelihood, possibility, likelihood, trust (belief), necessity (confidence); b)measures of outcome instead of the amount of damage, revealed in the nature of the event "where the scales tip" for a positive or negative outcome and in calculating the magnitude of the outcome of the event; introducing the following concepts: c) purposeful activity; d) habitat, given or artificially created; e) the environment for the destination of the activity, chosen or assigned. The meaning of the content of points (c-e) is that without the existence of expediency and the living environment, the subject of risk does not exist. In the proposed definition of risk, replacing the concept of probability with the broader concept of randomness is based on the following. The classical definition of probability considers random events with a stable frequency that decay into a finite number of equally probable cases. Of these, one event is determined as real, probable (by faith, clear, obvious) from many possible ones. The classical definition is often inapplicable when solving natural science and economic problems, since events fall into an infinite number of possible incompatible cases. Then the probability is not determined, but its existence is only postulated and a method is indicated for an approximate determination, which is called statistical [9]. The solution to this problem is considered in limit theorems, testing hypotheses about distribution parameters, and in the theory of estimation using the maximum likelihood method [10]. Replacing the concept of damage with a measure of the magnitude of the outcome is based on the practical use of various tools for assessing events - "heat maps" and risk matrices. They present positive (green), transitional (yellow), and red (negative) assessments of object states.

The understanding of risk with the semantics of "negative and undesirable" is explained by the historical concept and emphasis of the danger of the term risk. Since any life activity is associated with risk, this semantics should be considered incomplete and risk should also be understood in a positive sense. The structure and content of the elements of the subject of risk are incomparably more complex. A special case of the measure of randomness of an outcome is the calculable probability of an event. A special case of a measure of the magnitude of an outcome is the calculable damage of an event.

The risk management system offers tools for building a structured vision of the future and solving the problem of associated uncertainty. In civil aviation (CA), all aspects of its life are, to one degree or another, related to flight safety. In this sense, the flight safety system is presented as a means of eliminating all types of danger in civil aviation. In order to meet this requirement, it is proposed that the flight safety system be considered as a quality system, the main task of which is to regulate the relationship between the three basic characteristics that regulate the functioning of civil aviation: reliability, economics and law. In the process of regulation, such a system exhibits three interrelated functions or three directions in which the task of ensuring safety is solved. Problems of safety management system (SMS) should be considered in the context of the general state policy in the field of safety, the formation of which is carried out on the basis of the concepts of sustainable development and acceptable risk.

The safety of aviation activities is considered as the overall safety of the industry, including the following aspects: safety of aviation; aviation security; industrial safety; environmental safety; information security. Risk management is a key element of any safety management system, including the Safety Management System (SMS). In practice, several basic risk concepts are used:

- risk as a characteristic of potential danger, as the possibility of negative events that cause harm;

- risk as a measure of discrepancy between the results of decisions in terms of

their usefulness, and as the possibility of implementing worse alternatives;

- risk as the relationship between losses and profitability, including the concept of "chance" - receiving an unplanned benefit.

When managing safety risk, the main one is usually the first of the listed concepts, which corresponds to the ICAO approach, but in the actual production activities of civil aviation, the other two are also used.

The greatest methodological problems are associated with the identification of hazard factors and risk assessment. Since PD is defined by a state in which the risk of PD is maintained at an acceptable level, it is necessary to be able to estimate the value of the risk and compare it with a given acceptable level.

An analysis of various definitions of safety risk shows that the use of two groups of key terms is common:

- "probability", "opportunity", "possible danger", "threat", "risk factor", "hazard factor", characterizing the randomness of the impact of a negative factor, the probability, degree of possibility or frequency of the occurrence of a negative event;

- "loss", "losses", "damage", "deviation of the result from the planned", related to the consequences of this event.

There are many different risk management methods and different principles for their classification. It is proposed to divide all methods into phenomenological, deterministic and probabilistic.

The phenomenological method is based on determining the possibility or impossibility of an emergency process and gives a result if the current state of the components of the system under consideration can be confidently determined. It can be used to determine the comparative level of safety of various types of industrial installations, but is of little use for analyzing processes, so it is rarely used in civil aviation practice.

The deterministic method involves analyzing the sequence of accidents starting from the initial event. The progress of the process is studied and predicted using calculations and mathematical modelling. Disadvantages include the potential to miss important chains of events and the difficulty of building adequate models. Can be used in risk analysis for power supply, taking into account the ever-increasing capabilities of computer technology.

The probabilistic method involves both assessing the probability of an accident occurring and calculating the relative probabilities of one or another path of process development.

In the civil aviation practice, a combination of all three methods is actually used. Methods are also conventionally divided into qualitative, semi-qualitative (mixed) and quantitative. They can be deductive or inductive.

Methods of expert assessments. (Brainstorming, Delphi Method). At this stage of development of risk management, including aviation safety risks, the role of expert assessments is extremely important. Only an expert is able to process heterogeneous information based on his experience and intuitive ideas and synthesize an appropriate conclusion.

Expert assessments are used in cases where formal methods are too complex and the initial basis is insufficient to obtain an analytical solution. Both group and individual assessments are used. Application areas can be:

- assessments and likelihood of events and the severity of their consequences;

- forecasting the development of events;

- opinions on the work of other specialists or organizations.

Several types of expert assessments are used, which are essentially determined by the type of expert survey. The main types are: brainstorming, structured or semi-structured interviews, Delphi method.

It should be noted that expert activities in each area must be regulated by relevant regulations and carried out in accordance with certain methodological materials. Since there are no regulatory documents or expert

forecasting guidelines in the field of power supply management, airlines are developing their own methods.

The control chart method and the "what if?" method (Checklists, Structured What-If Scenario Analysis) are qualitative methods based primarily on examining the compliance of operating conditions with safety requirements. These methods are widely used in safety management systems. For example, the Canadian guide contains a special program called Q-850, in which checklists are tools for assessing hazards and risk reduction options. Next, a step-by-step scenario of the event and corrective action is drawn up. The "what if?" method declared as one of the main ones in the US FAA program.

The method of studying operational hazards (Hazard and Performance Study) is based on the fact that deviations from the usually observed level of various process parameters indicate the presence of existing or developing problems. The basic hazard and performance study procedures are similar to control chart procedures. In relation to technical systems [16], this is the deviation of specific variables from the nominal value. For a complex human-machine system, such as an a/c, these are deviations, inconsistencies and events identified during the assessment of operational activities.

This method includes: ***analysis of the types and consequences of failures, analysis of the types, consequences and criticality of failures, analysis of causes and consequences, analysis of hazards and operability.*** All of these methods involve examining each component part of the system for what brought it out of normal functioning and how the "abnormality" in the operation of this part affects the system as a whole. The combination of these methods is called Operations Analysis. A classification of failures according to the criteria "probability - severity" is provided. This classification can be specified for each object, technical device, part of the system (in our case, for each area of the airline's activity) taking into account its specifics. Thus, we arrive at the "risk matrix" (Matrix of consequences and probability), which in a number of manuals also provides for quantitative assessment. That is why these methods can be called "mixed" or "semi-quantitative". The main drawback of these methods is rightly noted - the difficulty or impossibility of using them to analyze combinations of events leading to an accident.

Preliminary hazard analysis (Preliminary Hazard Analysis) is an inductive method designed to identify hazards at all stages of system operation. The results obtained can be presented in various ways, for example, in the form of tables or a tree system. The method is recommended in a number of manuals. The Pilots Association IFALPA manual provides a technique for compiling a typical Preliminary Hazard List, using some of the methods we mentioned. The initial data (input) is all available information on the aviation safety: aviation events, hazardous external influences characteristic of the airline, recorded personnel errors, etc. Next, a list of the main hazards in the airline's activities (output) is compiled using the brainstorming method. An example of such a list is given, which contains more than 50 main hazards, for example, an aircraft collision in the air, dangerous weather phenomena, etc. Next, the development of a scenario using the "what if?" method is prescribed. An example of a hazard identification system is the Australian Transport Safety Bureau's INDICATE program. To a certain extent, preliminary analysis of factors is carried out constantly in the civil aviation activities. The effectiveness of this method will be determined, first of all, by the completeness of the accounting of dangerous situations. The method involves carrying out a large amount of work and constantly updating the list. The method is most useful for a small vehicle. For an airline with a large fleet of different aircraft, a wide flight geography, and a large charter program, compiling a list of dangerous situations will be a much more voluminous

and time-consuming task. The method of analysis of personnel errors (Analysis of the influence of human factors) is used for the qualitative assessment of events associated with personnel errors ("Method of analysis of personnel reliability"). The method is important for a human-machine system such as an airline.

A human error is an action that is performed or not performed under certain conditions. In probabilistic safety analysis, this issue is considered from the standpoint of personnel reliability analysis. Qualitative reliability analysis is carried out in order to determine the logical-time structure of the algorithm (instructions) for performing each personnel function in the specific conditions of their work in managing the system and the consequences of possible erroneous actions of personnel. An example of a method for qualitative assessment of personnel errors is the "Guide to Avoiding Errors in Maintenance," developed by Boeing. Quantitative characteristics of human errors are obtained using the Technique for Human Error Rate Prediction, the Accident Sequence Evaluation Program, or the Human Factors Analysis and Classification System. System), a description is given in the work of the Dutch Institute for Transport Safety (NLR)].

Fault tree and event tree analysis methods are effective methods for analyzing the conditions for the occurrence of undesirable events. Fault tree analysis is a method for identifying and analyzing factors that may contribute to the occurrence of the undesirable event under investigation (called the final event). Using deduction, the factors under study are identified, arranged in a logical manner, and presented in a diagram in the form of a tree that displays these factors and their logical relationship with the final event. The tree is built from top to bottom - from the final event to the initiating events, and then to the factors that cause them.

The event tree is built in the opposite direction - from the initiating event through intermediate ones and allows you to calculate the risk in terms of the probability of the main event. The event tree method is the main tool for probabilistic safety analysis.

In aviation practice, these methods are usually used individually to a limited extent, only for assessing private events. It is more effective to use a combination of both methods, called cause and effect analysis. The work begins with consideration of the final event and analysis of its consequences using YES/NO logical elements (fault tree method). The causes of the conditions or failures are then analyzed using the fault tree method. Foreign experience in developing similar systems (I-Risk, ARAMIS, WORM). The closest in scope is the Cause-and-Effect model for aviation security, which we will dwell on in more detail. The program was developed by a group of scientists from the Netherlands Institute for Transport Safety on behalf of the Dutch Ministry of Transport in the period from 2003 to 2009. using developments and software products from universities and research centers in many countries. The goal is to identify the sequence of events leading to an accident, assess the existing "safety barriers", assess the risk (as the likelihood of an accident and the severity of the consequences), and develop preventive measures. A list of types of events (33 types) that can occur at various stages of the flight has been developed. Causal models have been developed for each type of event at each stage of flight. This model is a sequence diagram of events and fault trees connected by a single Bayesian belief network. Failure trees were built based on descriptions of aviation accidents and incidents related to the accident category under consideration.

To estimate the probability of an accident, this model uses probability density distributions of hazards rather than point estimates. To obtain distributions, various databases were used, the main ones being:

- ICAO aviation events database;
- Database of airlines and airports.

Thus, the model uses the method of Bayesian analysis and Bayesian networks. Disadvantages of the model:

- the reliability of the calculations has not been checked; a simple comparison with similar assessment models is assumed;

- the model is developed for the safety of air transport as a whole, the features of individual aircraft are not considered, and accordingly, real airline operating data (failure data) is not used;

- the risk in this model does not include the amount of damage in monetary terms; only the loss of life and loss of aircraft are considered.

Tree methods are related to cause-and-effect analysis. For more complex events, the cause-and-effect diagram of the Japanese management theorist Kaora Ishikawa "fish skeleton" can be used.

Analyzing protection levels is important for an airline. It is a mixed method for assessing the risk associated with an adverse event or scenario. It aims to analyze the adequacy of measures to control or reduce risk and is based on the selection of cause-effect pairs and the identification of levels of protection that can prevent the cause leading to the undesirable effect. To determine the adequacy of risk reduction measures to an acceptable level, it is necessary to calculate the consequences.

Risk analysis using graph diagrams is the second (after the event tree) type of cause-and-effect diagrams. There are two types of graphs:

- transition and state graphs;

- flow graphs.

It is noted that graph-type models in the form of influence diagrams have long been used in security research models. Their advantage is the convenience of transition to iconic models and the derivation on their basis of mathematical formulas of the relationship between previously selected quantitative safety indicators and the main parameters of human-machine systems. The resulting analytical expressions can be used for a priori (preliminary) and a posteriori (actual) assessment of the level of risks. Process models using graphs are found quite often in research works on business safety, but in practical methods for managing security risks this method is not yet in sufficient demand.

Conclusions. In article conducted conceptual and terminological research in the sphere of aviation safety&security risk management. The existing normative description [risk = probability x consequences] for risk calculus is based on probability theory as a relatively developed branch of mathematics. This description is a single expression of the risk assessment. An analysis of known risk assessment methods has shown that many of them can be used to assess the risk for aviation safety security, however, at present, only qualitative risk assessment technologies are effectively used in individual aviation organizations, mainly the "consequences and probabilities matrix" method. The insufficient implementation of quantitative methods in civil aviation is associated, firstly, with an overestimation of the capabilities of the "risk matrices" recommended in the documents, and secondly, with the lack of specialized databases and computer programs on the market for processing the results of the analysis of deviations in the operational activities of the civil aviation.

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