

THEORETICAL AND METHODOLOGICAL APPROACHES TO THE INFORMATION BASE FOR AN AIRLINE'S FLIGHT SAFETY SYSTEM

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Abstract

This article presents a model and an algorithm for identifying, collecting, processing, analyzing and using data on risks at an airline (deviations from the standards in the activities of various airline units and personnel) to minimize them and thereby to achieve an acceptable level of flight safety. A methodology is also presented for formulating the composition of flight safety indicators, based on an expert approach, for the units and personnel of the airline, making decisions in this field in various areas of its activities. The model is based on the quality and flight safety systems that form part of an integrated management system at one of Latvia's airlines. The system makes it possible to analyze safety aspects on the basis of actual information drawn from various sources into the airline's information base, where it is collected, classified, stored and analyzed.

Keywords: airline, model information base, flight safety

Type of the work: research article

1. INTRODUCTION

On February 25, 2013, the ICAO Council unanimously adopted Annex 19 to the ICAO Convention, which entered into force in 2014 [1]. According to its requirements, the main goal of ensuring the safety of flights at each airline is to analyze, assess, control and take the necessary measures to reduce risks to an acceptable level. This means that a systematic approach is needed that would allow the identification and analysis of all possible risk factors in the airline and implementation of the actions necessary to minimize them and thereby increase the level of safety. Various methods can be used to assess risk [2, 3, 4]. At the same time, Annex 19 and other ICAO documents set forth general approaches to solving this problem [1].

Each airline seeks its own way of solving the problem, developing its own methodology and means of implementation, based on the recommendations of international organizations and the European Aviation Safety Organization (EASA) [5,6], as well as using the developments of other companies and enterprises [7]. It can be said that safety risk management is a relatively new area for airlines. Although significant research in this area in industry and transport has been going on for a long time, it is difficult to harness this experience in risk management, as the civil aviation sector has important characteristics that differ from other sectors [6,8]. As practice shows, each airline has developed various general

management models aimed at only focusing attention on the areas of the aviation enterprise that correspond to these models (aviation security, flight safety, labor protection, quality assurance, environmental safety, etc.). Work is underway here, which fundamentally consists in the accumulation of information and making initial risk assessments. Such information always circulates within the airline and in one form or another goes to the management. Although any manager actually deals with risks on a continuous basis, at the same time, a full-fledged analysis of risks and their inclusion in the flight safety / aviation security system is not carried out, which reduces the effectiveness of ensuring the appropriate level of safety in general [9].

These issues are most effectively resolved in airlines with an integrated management system. The integrated management system of an airline is a complex set of elements interconnected with each other through an information base, which must take into account, store and analyze the necessary data array through a built-in algorithm. For these purposes, it is necessary to develop an automated system for collecting, processing and using data on risks (deviations from the standards in the activities of various units and personnel of the airline) [10].

In this article, we propose an original approach to solving this problem. Our research is focused on developing theoretical and methodological approaches to the creation of an information database for such a system at one of the Latvian airlines with an integrated management system already in place. The proposed information base will allow the units and decision-makers in the airline in their areas of management to provide timely information on those areas where the risk of adverse events is greatest, as well as to identify trends in changes in flight safety indicators based on information flows from these areas of the airline's activities. This approach represents a transition to a new level of safety management at the airline level.

2. THE SEMIOTIC MODEL OF COLLECTION, INPUT, STORAGE AND USE OF AIRLINE OPERATIONAL DATA WITH AN AIRLINE INTEGRATED MANAGEMENT SYSTEM

Flight safety in airlines is ensured by an effective flight safety management system, which is a well-ordered approach to aviation safety that includes the required organizational structure, duties, statements, policies and procedures. The airline management system lists, stores, and analyzes the necessary data, operates on events at all levels based on a defined algorithm, and, at the same time, is compliant with ICAO and EASA flight safety requirements.

Considering airline operations as an array of production processes (areas of operations), it is possible to define an appropriate management system for each of these areas, which function in accordance with international requirements. The current standard of technical equipment in airlines allows non-conformities in all services and personnel to be detected, in each management system, but this information is not usually considered in maintaining flight safety due to the complexity of analysis and the storage of large amounts of data, especially if this data is provided as hard copies. Thus, it can be concluded that the nature of the non-conformances in the activities of almost all services and personnel at the airline is poorly studied, and the numerous preventive measures taken unsystematically are insufficiently effective. In spending a lot of time on making decisions regarding the errors and deviations identified, specialists dealing with these issues are unable to assess the degree of risk of their display during flight. At small and medium-sized airlines, it is quite possible to combine all these management systems and organize a single integrated management system. This type of management system is used in the airline mentioned in this article. As is well known, the complete mathematical formalization of processes in the aviation system is impracticable due to the diversity and complexity of the elements and factors affecting its functioning. In this regard, it is appropriate to use approaches based on the theory of semiotic systems. A model based on multi-layer logic (MLL) is used as one of the approaches to representing knowledge in a semiotic system. MLL is an integration of a logical approach and an approach based on semantic theory and is a convenient tool for formalizing the problem under consideration. A hierarchical abstract structure divided into blocks and levels makes it more compact, and by applying the appropriate mathematical apparatus

we solve the problem. Considering the above, the authors have developed a model of a system for collecting, storing, processing, and using the airline's operational data with an integrated management system. This is shown schematically in Figure 1.

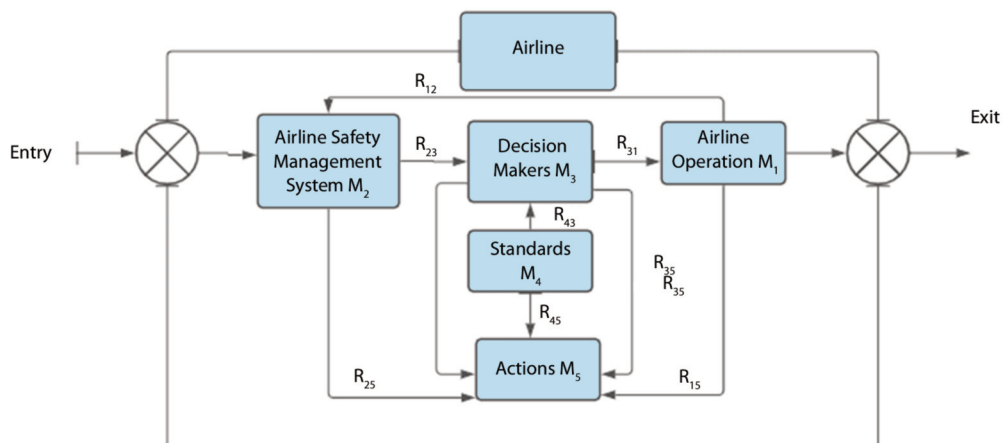


Figure 1. Model of a system for the collection, storage, processing, and use of airline operational data by an integrated management system.

Here subsystem M_1 – “airline operations”, a functional subsystem – management objects where undesirable situations S_1, \dots, S_n or more undesirable events develop on the ground and in flight. This is the place for undesirable events. They are characterized by the following productivity indicators:

- aircraft crew members flight hours;
- number of flights (landings);
- equipment operation time (h);
- number of passengers;
- etc.

Subsystem M_2 – the “information database” – contains operational deviations in all airline operational areas and undesirable events that occurred in flight and on the ground in a specific period of time. Here this information is collected, stored and processed. Undesirable events in flight occur due to faults in a variety of services. Information about such events also is collected here.

Subsystem M_3 – “organizations and people who make decisions” – includes company divisions and the people who make operational decisions and strategic decisions for a specified period of time in emergency situations. For each member of this subsystem, automated workstations must be equipped. Automated workplaces must be designed strictly in accordance with their intended function. This may be just a laptop or desktop computer with the ability to connect to the system, or it can be a set of computer services and software designed to automate the employee's work within their tasks.

Subsystem M_4 includes regulatory documents for the various areas of the airline's operations, as well as departments and people assessing the compliance of operations with the standards.

Subsystem M_5 includes “services and personnel developing safety performance plans”. At the airline level, they manage the level of flight safety and make decisions. At the same time, they are the sources of information for M_3 .

Thus, we have obtained a closed model of system dynamics, between the elements of which there is a constant exchange of information. The sequence of steps in the model is shown as directional arrows R_{ij} . As per this model, decisions can be made immediately (tactical decisions) and long-term (strategic) based on an in-depth and comprehensive analysis of the data entered in the M_2 database.

The following information links are shown between the subsystems:

R_{12} – risk factor as identified by the M_1 information database;

R_{23} – transfer of the results to M_3 subsystem for processing;

R_{31} – management decisions based on M_1 database information;

R_{35} – issuing of tasks for the development of enforcement measures M_5 ;

$R_{25} * R_{15}$ – transmission of information to the departments of the airline which are developing the measures M_5 ;

$R_{43} * R_{45}$ – submission of requirements and setup of standardized indicators M_3, M_5 .

3. ALGORITHM FOR ANALYZING ANOMALIES AND IRREGULARITIES IN THE OPERATIONS OF AIRLINE STRUCTURAL UNITS AND PERSONNEL IN CONDITIONS OF UNCERTAINTY

Analysis of deviations and violations in the functioning of services and personnel of the airline in accordance with Figure 1 that affect flight safety is an integral part of the decision-making procedure in and by the relevant departments and employees of the airline. In implementing this procedure, specialists of various categories and specialties are involved, who, before making any management decision, must collect and process information about the management object, make a judgment about the state of the object, compare this state with the model adopted, identify contradictions in this comparison, and formally define a set of proposed actions, from which to choose one or several of the highest priority. At each of the listed stages in developing a solution, it is necessary to carry out an analysis: the completeness and quality of information about the object, its state, etc. The versatility, multivariance, multicriteria and uncertainty of various situations significantly complicate the task of forming an algorithm for analyzing deviations and violations from the point of view of their impact on flight safety. By “anomalies” in the work of the structural divisions of the airline and its personnel, we mean errors that have led or may lead to the loss of the “crew/aircraft” system or the inability to perform the specified functions, and thereby create a risk of special situations in flight and during their fulfillment, aircraft accident or flight incident [8, 9, 10, 11].

At the same time, it is necessary to highlight two areas of analysis: analysis of deviations and violations to identify their consequences on flight safety and analysis of the causes and factors that led to deviations and violations in order to develop measures to prevent them. At each of the listed stages of developing a solution, it is necessary to carry out an analysis on the completeness and quality of information about the object, its state, and so on. The versatility, multivariance, multicriteria and uncertainty of various situations significantly complicate the task of forming an algorithm for analyzing deviations and violations from the point of view of their impact on flight safety. When developing a model based on semantic theory, this is a convenient means for formalizing the problem under consideration, applying the appropriate mathematical apparatus to it, and it is possible to solve the problem analytically.

We use this approach when developing an algorithm for **analyzing deviations under uncertainty**.

A generalized algorithm for analyzing deviations in the functioning of the airline's services and personnel to develop measures aimed at improving the level of flight safety is shown in Figure 1 in the form of a structural diagram. This algorithm uses a method of step-by-step analysis of the deviation as an event by the manager. As general feedback, the algorithm assumes control over the implementation of the measures taken to eliminate the consequences of the event and prevent its occurrence and monitor the state of the system element after the implementation of the measures. The algorithm is built considering the limited power of a particular manager and the possibility of involving a higher-level manager in the analysis

procedure and making a decision. The involvement of senior management in the analysis scheme is possible at any stage, and they can be satisfied with the activities of the subordinate and continue the analysis from the very beginning. In the case where this a lack of competence on the part of the manager or hesitation when performing certain stages, the algorithm provides for the possibility of involving other colleagues, more qualified specialists, specialists from other departments, etc., to solve specific problems in the analysis. They are called “experts” in the scheme. This scheme of analysis provides for the need to take prompt action on the event and the ability to take into account the events and activities related to it.

The algorithm we have developed serves the foundation for an automated information database concerning the flight safety system in the airline and the analysis of non-conformances that occur. Non-conformances in the activities of the departments and personnel of the airline were identified based on the analysis of operational documents used in a number of departments of the airline. Due to the extensive amount of the information, the block diagram of the algorithm is not presented in the article. This algorithm, in contrast to the already generally accepted algorithms and methods such as FMEA [12], FTA or RCM [13] which are used in maintenance and reliability assessment, takes into account inconsistencies in all functional areas of the airline’s integrated management system, unifying the quality assurance system, flight safety, aircraft maintenance, labor protection, etc. The indicators obtained on its basis are used by the units and personnel of the airline, making decisions on ensuring safety in these areas of activity. A more detailed description of the algorithm is published in [14].

4. METHODOLOGY FOR FORMULATING THE COMPOSITION OF INDICATORS OBTAINED BY THE DEPARTMENTS AND EMPLOYEES OF THE AIRLINE WHEN MAKING DECISIONS ON FLIGHT SAFETY

Improving flight safety is based on activities in two main areas: ensuring the basics of flight safety and preventing aviation accidents [1]. In essence, the first direction is ensured by compliance with certain regulatory requirements and determines the strategy for activities to improve flight safety, whereas the second is determined by the current state of the airline and is characterized by implementing the tactical plan. The management of **flight safety**, focused on the daily activities of the heads of the airline at all levels to solve the operational tasks of preventing adverse events, requires the implementation of specific tasks for the informational support of the system. The methodology proposed herein aims to determine and optimize the composition of indicators obtained by the departments and employees of the airline from the information base, Figure 1.

As indicated above, we applied this approach when developing an algorithm for **analyzing deviations in the functioning of structural divisions and airline personnel in conditions of uncertainty** [15]. In this regard, it would seem expedient to consult expert opinions on **formulating the composition of indicators**. The most rational method, therefore, would be to attract aviation specialists of the airline – the potential users of the developed information system. For this purpose, we developed an appropriate methodology based on surveys, using a special questionnaire distributed among experts. When drafting the questionnaires, the following was taken into account: the simplicity of the questionnaire filling procedure and insignificant time consumption; the anonymity of experts, which makes it possible to increase their engagement, ensures independence of judgments and the absence of “dictatorship” of any of the experts when making decisions; the addition or deletion of any indicators in a given expert’s individual list should not significantly change the final result of the examination; the principle of filling out the questionnaires should be familiar to experts from everyday life or professional activity.

However, the involvement of aviation specialists as experts among the heads of the middle and top-level aviation management does not guarantee high quality for all members of the expert group. The quality of an expert is influenced by work experience, completeness of understanding of the tasks being solved, psychophysiological characteristics, external factors and much more. To isolate an objective

component from the conclusions of individual experts, their quality is assessed. The analysis of various methods of organizing the examination made it possible to choose the “leader” method for solving the problem of forming the composition of indicators of the information database, which is a further development of the method of paired comparisons [16, 17]. The method is based on the statement that there is a path of length λ in the graph if and only if the matrix $A^\lambda \neq 0$ and there are no contours if and only if $A^\lambda = 0$ starting with some λ .

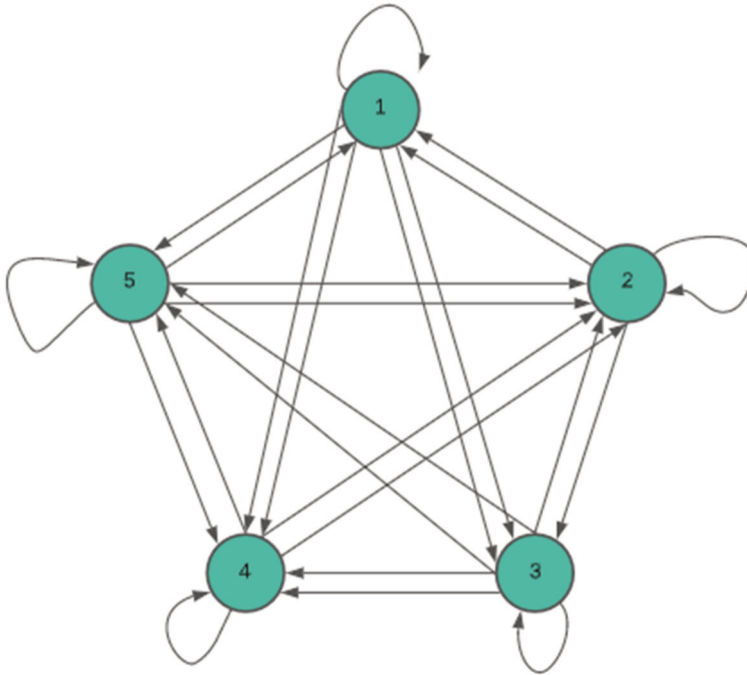


Figure 2. Preference graph.

The essence of the method is to find the “relative strength” of individual objects and their ranking in accordance with the obtained values of this strength. Its determination is carried out by finding the number of possible paths of length $\lambda (\lambda = 1, 2, 3, \dots, n)$ going from vertex i to vertex j on the preference graph (Figure 2).

Denoting through $P_{ij}(\lambda)$ the common element of the matrix A^λ , which is equal to the number of paths of length λ from i to j , by summing the elements by the rows of this matrix for each λ , we will find the “iterated strength” of the order λ of the object $a_i - P_i(\lambda)$, i.e.:

$$P_i(\lambda) = \sum_{j=1}^n P_{ij}(\lambda). \tag{1}$$

In general, the “relative strength” P_i of the object a_i will be:

$$P_i = \lim_{\lambda \rightarrow \infty} \frac{P_i(\lambda)}{\sum_{i=1}^n P_i(\lambda)}. \tag{2}$$

In practice, to rank objects a_i , it is enough to form the degrees of the adjacency matrix $A - A^1, A^2, A^3$ sequentially and compare the rankings of “relative forces” at each step with the ranking at the previous step. When the ranking of the “relative forces” coincides at two successive steps, the process is terminated and the ranking of the objects a_i is accepted in accordance with the ranking of the “relative forces” of these objects obtained. Upon completion of the ranking of objects, the most preferred object is assigned a rank of 1, the next 2, and so on. When processing expert tables from several experts, the sum of the ranks for each indicator in all the tables is calculated. The metric with the smallest sum of ranks will be the most preferred. Then the indicators are sorted in ascending order of the rank sums, and the sums themselves are normalized. For the purpose of processing the results of the expert survey, software was developed on computing machinery.

Creating groups of indicators that affect flight safety in an airline:

For the relevant automated workstations, a group of indicators is created, which are used by the departments and decision-makers in the field of safety in the airline according to Figure 1.

The approximate list of indicator groups can be as follows:

Group A. Indicators related to human factors.

Group B. Indicators related to deviations in the professional activity of the airline’s aviation specialists, along with the factors of disorders (health, conflicts, holidays, inspectors, holidays, etc.).

Group C. Indicators related to aircraft and their operation.

Group D. Indicators related to the organization of the airline’s management system.

* There may be other indicators of the groups.

The list of indicators forming the group (subgroup) is created by conducting oral surveys or distributing questionnaires. At this stage, the indicators of each group are divided into expert categories and specialties. Based on the results of the survey, preliminary lists of indicators are created, which are included in each of the groups (subgroups) separately for each category of experts and specialty. The next stage of the test will be the development of expert questionnaires for experts, grouped by category and specialty. Completion of questionnaires and processing with the list of indicators is performed by analogy with the ranking procedure of groups of indicators described above. After processing these questionnaires, the composition of the ranking indicators is formed and their groups for the information system are finally created for each automated workplace of the user.

5. DISCUSSION

The information database of the flight safety system at the airline level that we have developed and presented herein is based on the quality system as an integral part of an integrated management system. In the airline studied, the quality system (QMS) was developed and implemented in accordance with the requirements of ISO 9001: 2008, based on the TQM system (Total Quality Management). This is a universal model that best meets the requirements of all stakeholders (shareholders, management, personnel, consumers and society as a whole) and thereby allows both general management and focusing efforts on the situational fulfillment of individual requirements. The safety management system has also been implemented and is successfully operating in accordance with ICAO requirements, using existing resources as a basis by assessing the enterprise’s current safety management capabilities (including experience, knowledge, processes, procedures, resources, etc.). The functions of departments and personnel who are decision-makers, Figure 1, are assigned to both the flight safety inspectorate and the quality directorate, which coordinate their actions with each other and with the heads of departments, assisting them in performing their functions of safety and quality management.

However, both units report directly to the Director General.

The creation of the database in the form proposed allowed for:

- the expansion of the “geography” of the airline’s system management, thereby contributing to an increase in the degree of its orderliness;
- ensuring greater consistency of actions within the airline, thereby reinforcing the synergistic effect that the overall result from concerted actions is greater than the simple sum of the individual results;
- minimizing functional disunity in the airline, arising from the development of autonomous systems;
- management is much less labor intensive than the same for several parallel systems;
- the implementation of this system enhances the corporate culture, in which quality and safety are considered as equal basic values, which meets the requirements of ICAO in this area, considering that 2021 has been declared by the ICAO as the year of aviation safety culture.

6. CONCLUSIONS

1. An automated information database has been developed for an airline with an integrated management system, which facilitates identifying, processing and timely provision of information to decision-makers in the airline about those areas where the risk of adverse events is greatest, and also allows trends in changes in flight safety indicators to be identified. Based on information flows from various areas of the airline’s activities, the integrated management system allows the expected level of flight safety to be determined in a timely manner.
2. An algorithm for detecting and analyzing anomalies and violations in structural divisions and errors by airline personnel in conditions of uncertainty was presented, on the basis of which an automated system for collecting, processing and using data on risks (deviations from standards in the activities of various airline units and personnel) has been developed.
3. We presented the composition and methodology for the formulation of the composition of indicators obtained by the airline’s units and personnel who make decisions regarding flight safety.
4. We believe that this approach represents a transition to a new level of safety management at the airline level.

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