RIGA TECHNICAL UNIVERSITY
Faculty of Mechanical Engineering, Transport and Aeronautics
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Doctoral Student of the Study Programme "Transport"

DEVELOPMENT OF THE MODEL OF THE RELATIONSHIP BETWEEN FLIGHT SAFETY LEVEL AND PRODUCTION FACTORS IN THE AIRLINE

Summary of the Doctoral Thesis

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DOCTORAL THESIS PROPOSED TO RIGA TECHNICAL UNIVERSITY FOR THE PROMOTION TO THE SCIENTIFIC DEGREE OF DOCTOR OF ENGINEERING SCIENCES

To be granted the scientific degree of Doctor of Engineering Sciences, the present Doctoral Thesis has been submitted for the defence at the open meeting of RTU Promotion Council on April 30, 2019 at the Faculty of Mechanical Engineering, Transport and Aeronautics of Riga Technical University, 8 Lauvas Street, room 218.

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DECLARATION OF ACADEMIC INTEGRITY

I hereby declare that the Doctoral Thesis submitted for the review to Riga Technical University for the promotion to the scientific degree of Doctor of Engineering Sciences is my own. I confirm that this Doctoral Thesis had not been submitted to any other university for the promotion to a scientific degree.

Ruta Bogdane ……………………………. (signature)

Date: ………………………

The Doctoral Thesis has been written in Latvian. It consists of Introduction; 4 chapters; Conclusion; 25 figures; 12 tables; the total number of pages is 98. The Bibliography contains 124 titles.

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GENERAL DESCRIPTION OF THE DOCTORAL THESIS

Topicality of the research

The main objective of the airline is to ensure the air transport of a particular route with minimal materials, energy and time losses without harming passangers and the environment, preserving transport objects (in terms of quality and quantity) and preventing damage to technical assets or loss of aircraft, including infrastructure and other property involved in the carriage process. In order to achieve this, it is first and foremost to ensure a high level of flight safety in the airline.

As of 2013, ICAO requirements for the introduction of a flight safety system in civil aviation entered into force based on risk analysis, risk assessment and implementation of measures to reduce them to an acceptable level and to control them. However, so far there has been no unified approach to managing the security risks of the airline, and the guidance in ICAO documents is not sufficient to create an effective flight safety system. Thus, each airline is looking for its own way of solving the problem by developing its methodology and its means of implementation based on the recommendations of the International and European Aviation Safety Organization (EASA), as well as using other companies or aviation industry practices in the world.

Risk management in the field of civil aviation safety is a relatively new direction. A major study in this area was carried out at the beginning of this century. It is quite difficult to use the risk management experience accumulated in other areas of activity, as the civil aviation industry has important features that are different from other industries.

In this work, the author analyzes various solutions to this problem and offers his approaches to flight safety.

At the same time, an analysis of the airline's operational risk factors is carried out, which is traditionally divided into three categories:

- environmental factors;
- technical factors;
- human factors.

The study will add a fourth category – a group of economic factors. It includes factors such as quantitative air traffic performance, the airline's financial situation, infrastructure costs of the airline and fleet, salaries of different categories of employees, etc. All of these factors are part of a risk-based airline safety system.

The aim of the Doctoral Thesis

To develop a flight safety system based on risk, including economic risks, in the airline.

Tasks

To achieve this aim, the following main tasks have to be addressed:

1) analysis of the airline's management system in various fields of its activities and their interaction (quality, flight safety, environmental safety, provision of services, etc.) to detect deviations in the company's operations;

2) development of a flight safety **Information Risk System** (IRS) covering all types of risks, including economic risks, and development of a model for assessing quantitative indicators of flight safety in the airline;
3) development of the airline's quality model and methodology of the analysis of interconnection between the flight safety and economic factor;
4) development of an airline's work planning model taking into account the mutual balance between economic and safety indicators;
5) development of methodology for assessing the quality of integrated management system and its impact on the competitiveness of the airline;.
6) testing of the developed models with the airline.

Research object – airline flight safety management system.

Resarch subject – an airline flight safety management model that is based on risks, including economic ones.

Research place – airline "Airlines" Ltd. (adopted name in the Thesis).

Research methods

The research uses the following scientific methods:

- mathematical modeling;
- probability theory;
- processing of statistical data using *Microsoft Office Exel 2016* software;
- expert assessment.

Theoretical and methodological tools used

- Contribution of scientists to management theory, the efficiency of decision-making and management systems, marketing methods, management, analysis and synthesis methods, economical and mathematical models.
- Systematic analysis, functioning and development of the airline's structure.
- Semiotic and mathematical modeling of enterprise management processes.
- Risk assessment methods IATA (IOSA), SHELL, DEMATEL.
- ICAO, IATA, EASA, ISO, CAA documents and "Airlines" Ltd. statistics and documents.

Scientific novelty

- Methods for assessing airline non-compliances and their inclusion in the safety management system.
- Risk model of airline safety information system, which includes economic indicators.
- Methods of analyzing the quality of transport services and the economic indicators of the airline.
- Planning of the management model, organization and work, taking into account the ratio of economic indicators aginst flight safety indicators.

Practical significance

Implementation of the developed models in practice will allow the airline:

1) to ensure adequate air transport quality at a high level of safety and regularity of flights;
2) to identify the airline's perspectives and development;.

3) to perform qualitative and quantitative assessment and coordination of departmental activities;
4) to reduce economic losses by improving the operation of the entire airline.

Theses to be defended.

- Flight safety assessment model based on risks, including economic ones.
- Risk model of airline flight safety information system.
- Method of analysis of mutual regularity between the quality and level of flight safety and economic indicators in the airline.
- Methods of assesing the quality and competitiveness of the airline, including flight safety indicators in interaction with economic indicators.

Results of research

- The concept of the airline flight safety system and a model of its information base was developed, which is a statistical device that was designed to collect and analyze nonconformance statistics related to the company's services and staff in relation to the company's performance and flight safety level. A model for assessing quantitative flight safety indicators was also developed based on the information provided by the airline's integrated management system and tested at "Airlines" Ltd.
- A model of quality interrelationship with the airline's quantitative results was developed, where the level of flight safety is a key factor. Pocesses of the airline were defined and, based on the analysis, an optimal ratio of changes in the performance over a certain time interval was obtained
- A methodology for measuring the interaction of indicators was developed, which determines the correlation of the quality level with the airline's economic indicators, and a system of indicators that describes the operation of the airline during the relevant period and the basic principles of its ranking was developed, as well as the norms of these indicators (benchmarks). A methodology for assessing the difference between actual and normative indicators as well as the criteria for assessing the flight safety level of the integrated quality management system was also developed.
- Approbation of the developed models based on the results of the operations of "Airlines" Ltd. indicated that the reasons why the actual indicators do not conform with the normative (standard) are sufficiently precise, informative and reliable. It allows to identify the following:
    - changes in economic conditions and indicators that are associated with a certain reduction in the level of flight safety;
    - economic indicators that reduce flight safety;
    - trends in economic indicators that reduce the level of flight safety;
    - economic indicators, changing the relationship between investment and production costs of transport products, which would improve the level of flight safety.

- The airline's work planning model has been developed and tested, taking into account the relations between economic indicators and flight safety levels, which include operational impact on the processes of the integrated management system of the airline.
- The study confirmed the theoretically important relationship – the closer the actual figures D_1, D_2, D_3 relative to the normative (the higher the correlation between them), the greater is the level of flight safety. The economic nature of this connection is as follows: the more proportional is the distribution of economic indicators in order to develop the technical basis of materials (D_2) and the airline's resource allocation and deployment (D_3), the higher is the quality and flight safety.

Accuracy of research results

All obtained research results are based on the author's practical calculations, regulatory requirements and airline documents.

The mathematical models, methods, algorithms, diagrams and organizational structures developed by the author have been tested and implemented in practice in methodological and regulatory documents, taking into account airline standards, airlines' practice, including the practice of international airline companies.

Approbation of research

The work has been presented in 3 international scientific conferences – in Poland, Lithuania and Latvia, and in 6 publications in 3 scientific journals.

International scientific conferences

1. Riga Technical University 58th Scientific International Conference, Riga (Latvia) 12–15 October 2017, "Process approach to ensure safety in an airline", R. Bogdane.
2. Riga Technical University 58th Scientific International Conference, Riga (Latvia) 12–15 October 2017, "Development of a Model for Improving the Flight Safety System in the Airline", R. Bogdane.
3. Conference on scientific aspects concerning operation of manned and unmanned aerial vehicles, Deblin (Poland), May 20–22, 2015, "Improving safety and regularity of flights in airline based on aircraft' technical operation processes improvements", R. Bogdane.
4. 11th International Conference "Research and education in aircraft design", Vilnius (Lithuania), 15–17 October 2014, "Process approach to airline flight safety", R. Bogdane.
5. Riga Technical University 55th Scientific International Conference, Riga (Latvia) 17 October 2014, "Assessment of the efficiency of the management system for preparing aircraft for the flight in emergency situations", R. Bogdane.

Research publications

1. Bogdane R., Gorbačovs O., Sestakovs V., Arandas I. "Development of a model for assessing the level of flight safety in an airline using concept of risk". Procedia Computer Science, 2019, in Press, pp.1-10. SCOPUS. ISSN: 1877-0509. DOI information: 10.1016/j.procs.2019.01.150
2. Bogdane R., Bitins A., Sestakovs V., Yasaretne Bandara Dissanayake. "Airlines Quality Assessment Methology Taking Into account the flight safety level based on factor

analysis”. Transport and Aerospace Engineering. Nr. 6, 2018, pp. 15–21, ISSN 2255-968X. e-ISSN 2255-9876. Available: doi:10.2478/tae-2018-0002.
3. Bogdane R., Yasaretne Bandara Dissanayake, Anderasone S., Bitins A. “Development of an Information Database for the Integrated Airline Management System (IAMS)”. Transport and Aerospace Engineering. Nr. 4, 2017, pp. 11–21, ISSN 2255-968X. e-ISSN 2255-9876. Available: doi:10.1515/tae-2017-0002.
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5. Bogdane R., Šestakovs, V. “Development of Mathematical Model of Integrated Management System for an Airline”. In: 4. Starptautiskā zinātniskā konference “Transporta sistēmas, loģistika un inženierija-2016”, Latvia, Rīga, 30 June to 1 July, 2016. Riga: Rīgas aeronavigācijas institūts, 2016, pp. 5–12.
6. Bogdane R., Šestakovs V., Dencic, D. “Development of the Mathematical Model of Integrated Management System for an Airline”. Transport and Aerospace Engineering. Nr. 3, 2016, pp. 44–51, ISSN 2255-968X. e-ISSN 2255-9876. Available: doi:10.1515/tae-2016-0006.
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8. Bogdane R., Vaivads A., Dencic D. “Evaluation of Management System Effectiveness in the Preparation of the Aircraft for Flight in Faulty Conditions”. Transport and Aerospace Engineering, doi: 10.1515/tae-2015-0002, 2015/2.

Structure of the work

The work contains an introduction, 4 chapters, conclusions, a list of literature, 25 figures, 12 tables. The total number of pages is 98. The Bibliography contains 124 titles.

Chapter 1. Analysis of the current requirements of flight safety.

In this chapter, based on the analysis of current flight safety requirements and practices, the author presents his approach based on risk assessment, including economic risks.

Chapter 2. Process approach to risk assessment, including economic risks, for ensuring flight safety in the airline.

This chapter presents the process approach model for ensuring flight safety in the airline, the structure of the risk information system and the methods for assessing flight safety level.

Chapter 3. Developing a quality model, taking into account flight safety level.

In this chapter a model of interconnection of safety indicators with economic indicators of the airline’s over a certain period of time has been developed.

Chapter 4. Approbation of proposed methodology based on “Airlines” Ltd. data.

The approbation of the models developed in this chapter provides the results of models based on “Airlines” data.

Conclusions.

This chapter provides the conclusions about the results of research carried out and the approbation of their results in the airline’s practical activities.

1. ANALYSIS OF THE CURRENT REQUIREMENTS OF FLIGHT SAFETY

The safety of flights in civil aviation is based on the use of the concepts of aviation accidents, incidents and special situations, determination of the causes of their occurrence, based on the results of investigation, the investigation of information by means of objective controls, etc. However, the experience of investigating aviation accidents and incidents indicates that prior to their ocurrence there have been several warning signs in the airline company in the form of risk factors, such as deviations from the regulatory requirements in providing services and in activities of personnel.

ICAO documents, which came into force in 2013, define flight safety as "a condition in which the risks associated with aviation activities are reduced to an acceptable level and controlled".

In order to realize the airline's main task of "ensuring an adequate level of flight safety", it is necessary to take the necessary steps to analyze and evaluate, and to reduce and control risks to an acceptable level. This means that there is a need for a systematic approach to identify and analyze all potential risk factors in the airline and to implement the measures needed to reduce them and thus increase the level of flight safety.

At the same time, ICAO develops general guidelines for risk assessment issues, and each airline can apply its own methods.

The applicable risk methods are described in the airline documentation and their approval by the civil aviation authority is mandatory.

Until now, there is no common approach to risk management to ensure flight safety in the airline, and ICAO documents are not enough to create an effective flight safety system.

Thus, each airline is looking for its own way of solving the problem by developing its methodology and its means of implementation based on the recommendations of the International and European Aviation Safety Agency (EASA), as well as using practices of other companies or aviation industry in the world.

1.1. General description of the risk

In fact, risks are present in all areas of human life. The concept of risk is closely related to the basic processes of human life. Therefore, today there is no unity in the formulation of risk terminology. The ICAO Safety Management Guide defines risk in several ways.

It is assumed that the risk as a mathematical size, according to ICAO, is the expected level of risk for a given event. Risk is not a probability. The main task of the flight safety theory is to predict the probability of a disaster with the probability of "almost zero".

According to ICAO data, the level of flight safety is the number of catastrophic situations per flight hour or flight.

At the same time, according to standards, in a catastrophic situation, life-saving is assessed as an almost impossible event quantified as one event per one billion flight hours (10^{-9} hours).

Damage caused by civil aviation can be expressed not only in material terms. It could also be a reduction in the level of flight safety, failure to provide flight safety, a reduction in the airline's competitiveness, etc.

Thus, when assessing the risk associated with a particular hazard, both the likelihood of a hazardous situation and the severity of the potential consequences must be taken into account.

Risk management in the field of civil aviation safety is a relatively new direction. An essential study in this field was carried out at the beginning of this century.

It is quite difficult to use the risk management experience accumulated in other areas of activity, as the civil aviation industry has important features that are different due to:

- the complexity of the Aviation Transport System (ATS);
- high uncertainty regarding external threats;
- the special and diverse role of people in civil aviation;
- the global nature of civil aviation.

This means that, with regard to the use of the concept of risk, in order to ensure flight safety, the airline has to apply a certain specificity.

1.2. Risk concept in civil aviation

There are four types of occurances in aviation, taking into account the consequences of a possible risk factor for flight:

- catastrophe (incident with human victims (loss of life));
- accident;
- a serious incident;
- incident.

For all these types of undesirable events, the ICAO sets quantitative index "1 : 10 : 30 : 600" indicating that factors contributing to the occurrence of more severe events can be the result of hundreds of less severe events and can be identified prior to the occurrence of a major accident (Fig. 1.1).

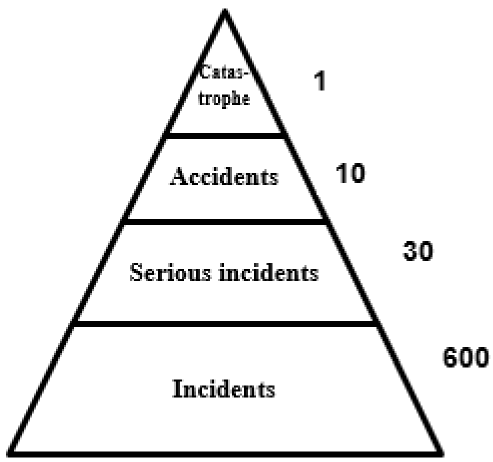


Fig. 1.1. ICAO event pyramid.

In the event that all possible abnormalities in the operations of the airline's staff and airline services are taken into account, the ICAO aviation event pyramid is supplemented by another level known as the other negative event level (Fig. 1.2).

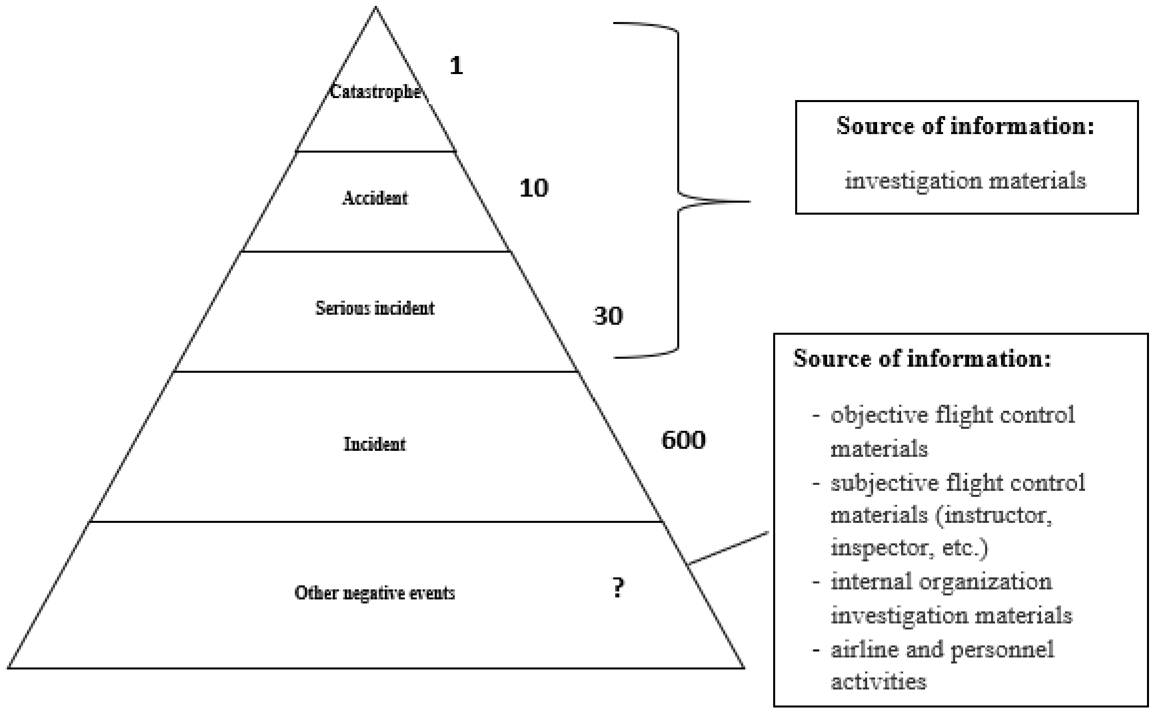


Fig. 1.2. ICAO event pyramid supplemented.

The most complex is the identification and collection of risk factors. Information about these events in a centralized manner is not usually available.

At the same time, the availability of airline's current technical equipment makes it possible to identify inconsistencies almost in all airline processes and airline personnel actions.

However, many airlines do not have this information because it is difficult to analyze and store due to large volumes of data, especially if they are available in paper form.

So, we can conclude that the inadequacies of the airline's entire processes and staff are insufficiently researched, but the preventive measures taken are not effective enough.

In order to solve this problem, it is necessary to identify the airline's existing hazards and to collect all possible risks, to record them in order to use in the management of the flight safety system.

1.3. Risk categories according to hazard level

All possible risks depending on the degree of danger are usually classified into the following categories (Fig. 1.3):

– unacceptable risks – high risk (A);

– acceptable risks – low risk (Z);
– the level of risk between unacceptable risks (high risk (A)) and acceptable risks (low risk (Z)) when compromised situations have to be taken into consideration between these two risk levels.

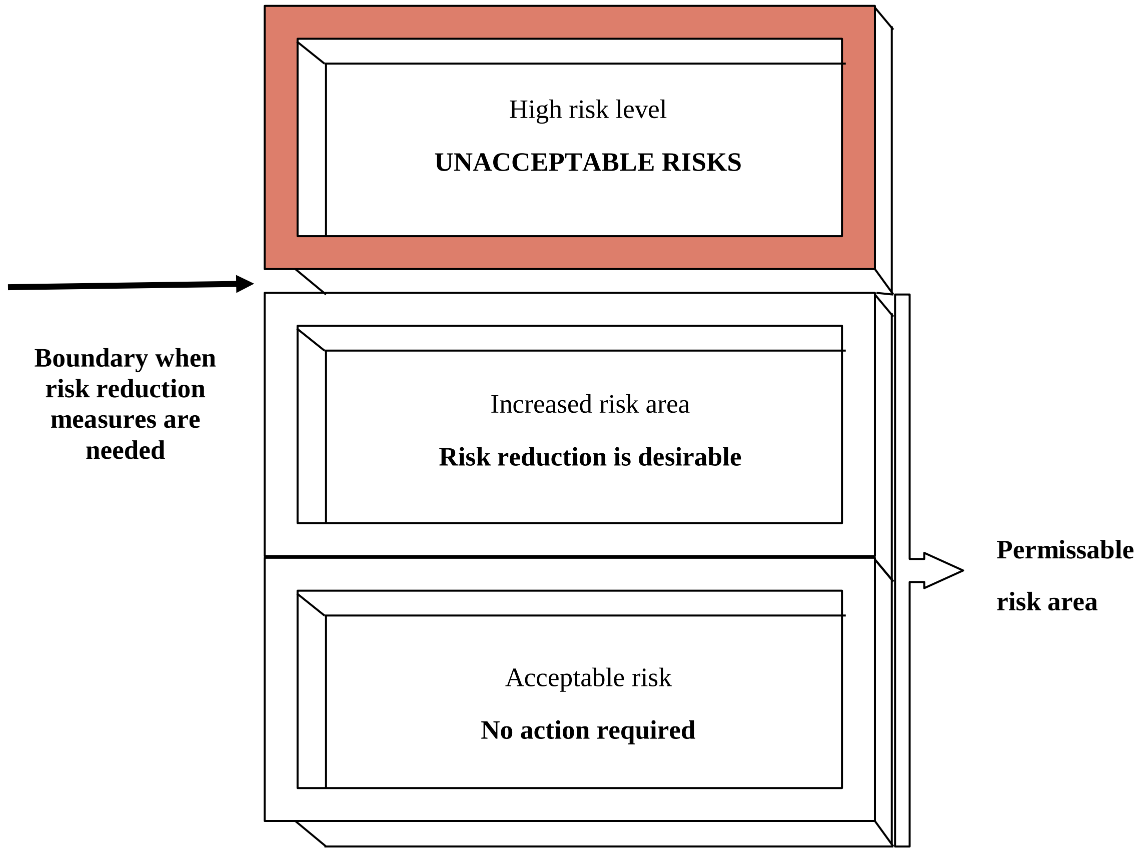


Fig. 1.3. Risk breakdown depending on the degree of danger.

If risk factors are not acceptable, an attempt is made to reduce the level of risk to an acceptable level. If it is not possible to reduce the risk to an acceptable level, the risk can be considered acceptable if:
– the resultant risk is lower than the previously unacceptable level;
– the risk was reduced to the lowest possible level;
– significant material benefits are obtained or the proposed changes are significant enough to justify the acceptance of this risk.

In order these conditions to be met, it is necessary for the risks to be classified as acceptable. Assigning a lower risk means that risk reduction is still practically impossible or the costs associated with it substantially outweigh the material costs.

1.4. Analysis of risk evaluation methods

Different methods can be used for risk assessment. Three risk management methods are considered (Fig. 1.4):
– reactive method – based on past events;

– proactive method – based on an analysis of accidents that are still being investigated in an airline;
– predictive method – it is necessary to identify and analyze possible threats in assessing the risks involved.

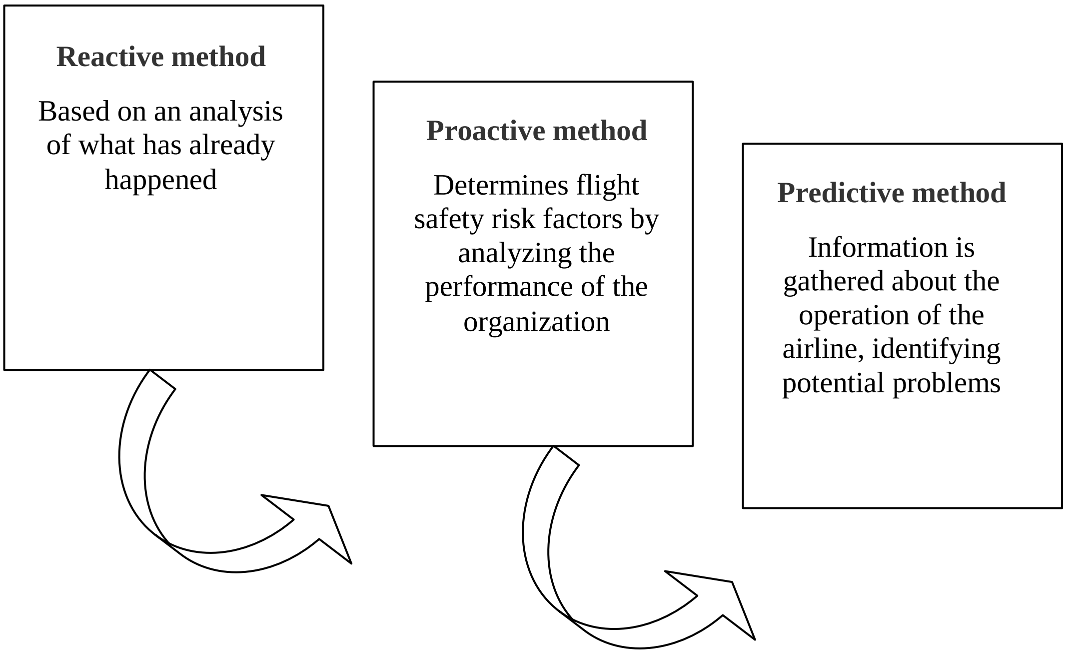


Fig. 1.4. Flight safety assurance (risk assessment).

All three methods require the development of appropriate measures to eliminate threats and reduce risks.

1.4.1. Reactive approach to eliminate aviation occurances

The essence of the reactive approach is the system for alerting accidents and incidents, the aim of which was to strictly comply with regulatory requirements and to introduce preventive recommendations developed as a result of the investigation of the above-mentioned events.

The results of the incident investigation revealed that the organization was working with systemic defects, which nobody wanted to detect until they caused the accident.

Actions to improve the system are not implemented or improvements are made separately.

1.4.2. Proactive approach to eliminate aviation occurances

The practice of investigating aviation events has convincingly shown that the existence of any hidden disadvantage in an organization may, in some circumstances, lead to its transformation as a cause for a negative event.

Therefore, ICAO has proposed a radical change of approach – to work continuously in the field of aviation accident investigation in order to identify and eliminate hazards in each airline's process.

Thus, the above-mentioned approach gained a definition – a "proactive approach", i.e. a preventive measure.

On the basis of the above, flight safety is a qualitatively different concept and is considered to be a system in which the risk to humans or property is reduced to an acceptable level by continuous identification of hazards and control of risk factors.

Thus, the proactive approach is a new concept focused on preventative work for identifying and preventing risks and threats to anticipate negative events before they occur.

1.4.3. Predictive approach to eliminate aviation occurances

This approach is based on the finding of deficiencies before they occur. Thus, in a predictive system for the identification of risk factors, data from different sources of information are collected and maintained, which may indicate the cause of possible risk factors.

The essence of the forecasting system is the statistical systems that collect and analyze a large amount of operational data that themselves are not significant and then combine it with reactive and proactive data to collect data on risk factors.

Thus, based on these aggregated data, comprehensive information is prepared that allows the airline to maneuver by introducing these or other risk mitigation measures.

Using a predictive approach, accident prevention is based on predicting the risk of potential occurrences. One of these methods is the "disaster recovery shortest roads" method, which is based on a hazard analysis in various J. Reason schemes that are automatically created using a computer module. This allows us to assess the risk of a disaster and implement risk management. The following methods are used to assess the hazard level on the basis of the "search for the shortest path leading to a disaster" or the J. Reason scheme:

1. SHELL concept – for building an aviation system model. The SHELL diagram is used in the ICAO recommended form (Fig. 1.5).

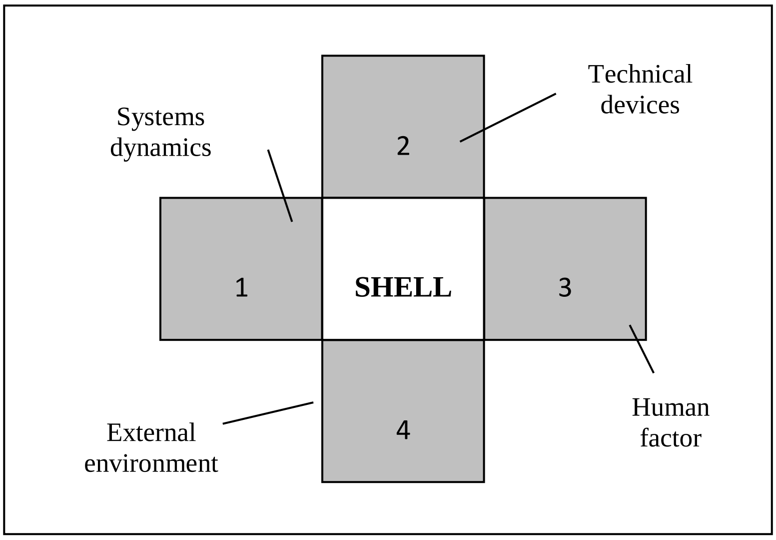


Fig. 1.5. SHELL diagram.

Using the J. Reason chain method allows to calculate the potential level of risk in the system without using probability indicators. There are also other different complexity risk assessment methods used in different areas of human activity.

2. DEMATEL is one of the methods of decision-making based on a causal analysis developed in 1972 at the Battelle Memorial Institute in Geneva. It is a rather complicated method used in various projects, including solving global problems in the scientific, political and economic fields. This method uses matrices and charts to visualize the structure of a causal relationship and allows it to be split into causative and consequential groups in order to facilitate the decision-making process. DEMATEL is based on the theory of graphs, which allows to visually identify the causal relationships, highlight the key ones and assess the causes and consequences of them. There are a number of other approaches to identifying and analyzing risks and, on the basis of this, taking decisions to reduce them, such as the following methods:

– ARMS (Aviation Risk Management Solutions) – methodology that was developed in 2007 as a new methodology for evaluating operational risks;
– HFACS (Human Factors Analysis and Classification System) – a method for analyzing risks that helps improve peronal performance, reduce workplace injuries and improve occupational safety;
– expert valuation method.

Risks are assessed qualitatively or quantitatively. Using qualitative methods, risks are assessed predominantly subjectively.

In practice, quality risk assessment methods are the most commonly used. Numerical or quantitative risk assessment has the following benefits compared to a qualitative risk assessment method for identifying potential hazards, as it allows an objective assessment of the degree of risk and comparisons with regulatory requirements and the development of risk according to the risk management system.

The quality risk assessment method is based on the so-called “risk matrix”. The permissible risk to flight safety associated with hazards or the probability and severity of an incident is indicated by the risk index (R) and is determined by formula

$$R = K_p K_s, \tag{1.1}$$

where R – risk index;

K_p – the probability level of a particular flight situation, for example due to staff deviations;

K_s – the severity of the consequences of a special situation in flight.

Quantitatively, each of these indicators is expressed in points. As a result, we obtain a “risk matrix” with an assessment system depicted in different colors depending on the degree of danger (Fig. 1.6). The risk is expressed in points, and its acceptability or inadmissibility is determined by the airline using different methods, such as the expert method. Figure 1.6 represents the risk assessment matrix in colors and points due to the deviations of the airline technical staff’ activity.

	Risk level			
K_s / K_p	16	8	4	1
4	**64**	**32**	16	4
3	**48**	**24**	12	3
2	**32**	16	8	2
1	16	8	4	1

Fig. 1.6. Risk assessment system due to technical staff deviations.

The expert evaluation method is also used to assess the risk.

2. PROCESS APPROACH TO EVALUATE RISKS, INCLUDING ECONOMICAL RISKS, TO ENSURE FLIGHT SAFETY IN AN AIRLINE

All operation of the airline can be considered as a single set of processes.

In an organization's operation, these processes interact in a complex way, forming a unified system or process set. Processes are an interconnected set of tasks that deliver the benefits to the consumer and meet their specific needs. Any process can be depicted as a set of units (resources, organizational units), functions (actions) and events. This management approach, based on the process approach, can be called a "process approach".

Using the "process approach" in the airline in quality control matters in air transport services means that these services can be portrayed as system flows and factors that are in continuous motion and interaction, i.e., a set of processes.

The company's operating result is the quantitative amount of air transportation and other transport services. This is the result of the process.

In turn, they all characterize the quality level.

Particularly important for airlines are social quality indicators, such as:

- flight safety;
- the level of services;
- environmental impact;
- flight regularity;
- speed, etc.

2.1. Airline Information Risk System (IRS) development

The information management system of an airline must take into account, store and analyze the necessary data, and work with all the events, as shown in Fig. 1.2.

Using this approach, we can assume that AIIMS, which includes information about hazardous situations, is part of the airline's integrated management system.

IRS is a statistical tool and is intended to study the statistics of adverse events related to the performance of the airline. Taking into account all of the above, IRS can become the main organizational tool aimed to improve the quality and level of flight safety in the airline.

The effectiveness of flight safety can be improved by timely identification and elimination of hazards both in the operation of the airline and in the processes related to the operations of the airline's personnel.

IRS provides the following:

- extends the airline's management system to improve its operations;
- ensures the coordination of activities (processes) in the airline, thereby contributing to the overall performance of the company exceeding (make better) the sum of individual outputs;

– reduces the inconsistency of operational processes in the airline that may occur when developing separate management systems;
– establishment and management of IRS is not as labor-intensive as the establishment and management of several parallel systems;
– improves corporate culture, in which quality and flight safety are considered to be equivalent to core values.

In this case, the flight safety management system can be mapped schematically as shown in Fig. 2.1.

Airline integrated management system is a set of elements that IRS combines together.

The results of IRS in general depend on the quality of work of each element. Thus, on the basis of the above, IRS plays a key role in the operation of an integrated management system. Accordingly, it imposes certain requirements for the operation and functional safety of IRS.

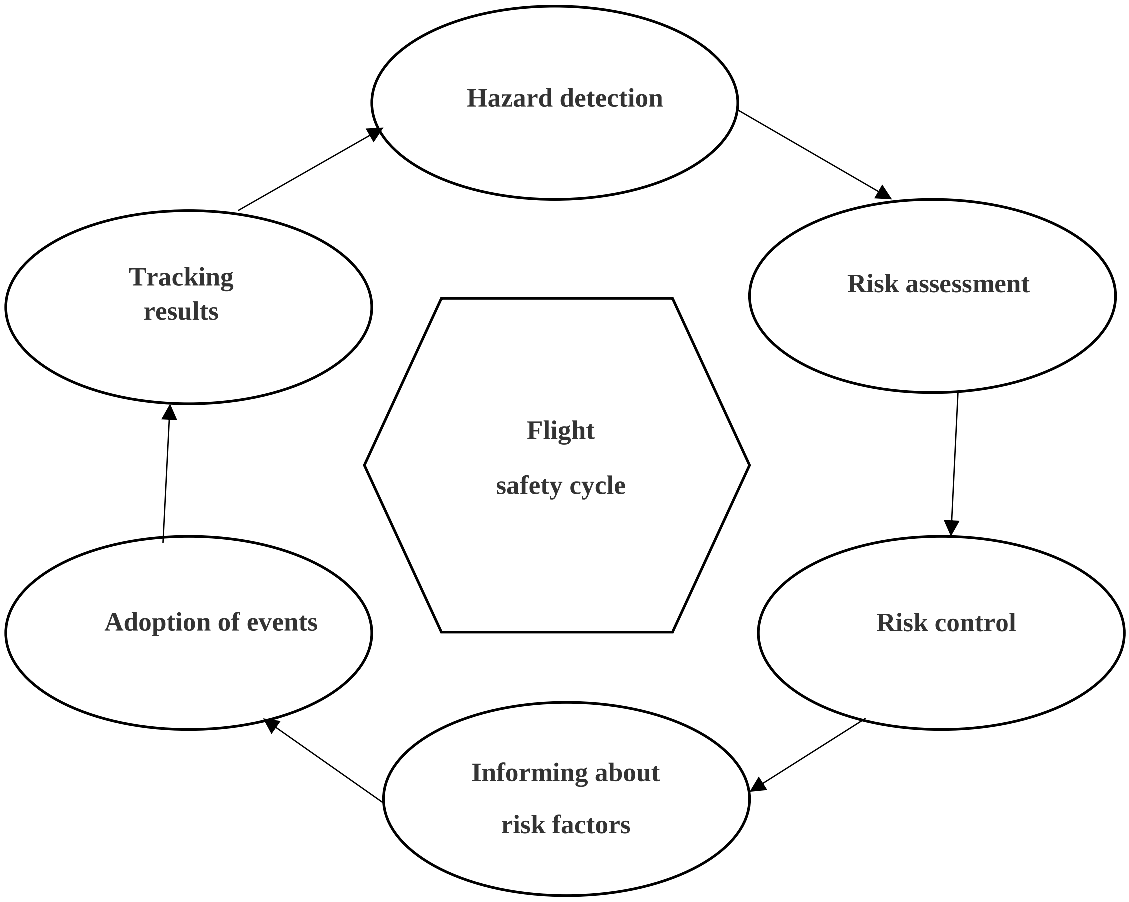


Fig. 2.1. Structure of the airline's information risk system (IRS).

2.2. Determination of quantitative indicators of flight safety based on IRS

Taking into account all the abovementioned, the airline's integrated information management system takes into account and stores all necessary data for analyzing the risks and adverse occurrences of the flight.

These data are:

- accident and incident investigation reports, flight data monitoring (FDM) and their results; individual (or anonymous) flight incident reports that include special situations during the flight, including the causes of their occurrence, as well as the flight stages in which they occurred; audit results; the airline's relevant departmental processes and airline personnel mistakes;
- data on the volume of work to be performed:
  - flight hours of the aircraft;
  - number of flights;
  - the number of passengers and cargo transported;
- data describing the operating conditions of the airplane, such as the state of the external environment (weather, ornithological situation, traffic volume, etc.).

All data are collected in a differentiated manner according to aircraft type, class, causes of danger, event types, flight stages, etc.

All information on adverse events during the flight is obtained from the analysis of the causes of their occurrence.

In order to ensure a complete range of data on adverse events, irrespective of the procedure for investigating adverse events (investigation, flight analysis using FDM, received individual reports, etc.), it is necessary to establish a root cause analysis scheme that must be uniform and predict the dynamics of possible causes during the flight.

The author proposes a method for calculating the dynamics of variations in flight safety level indicators, assessing the special situation of flight hazards in case of risk factors.

In order to carry out a risk assessment, we will use flight safety standards that determine the occurrence of special situations during flight (Fig. 2.2).

Negative event groups are indicated as follows:

- **SLA** – complicated flight conditions;
- **SS** – difficult situation;
- **AS** – emergency situation;
- **KS** – catastrophic situation.

In order to collect data on inconsistencies between the services provided by the airline and staff, we will additionally implement a negative event group – **BSLA**: an event without complicated flight conditions.

As quantitative indicators we will use:

- $P_{\bar{I}S}(O)$ – the probability of occurrence of special situations during the flight caused by the risk factor during the flight;
- $P_{\bar{I}S}(\Sigma)$ – the total probability of the special situations caused by the risk factor.

When assessing the risk factor Q_i, we will use the following conditions.

Since adverse event factors, flight crew following actions to correct their consequences and the result of a flight are occasional events, the flight safety level is assumed as probability that the flight result is unsuccessful, i.e., a catastrophe may occur.

We will denote this indicator as the flight risk level Q, determined by formula

$$Q_i = q_i p_{is}, \tag{2.1}$$

where q_i – probability of occurrence of i-th adverse event (incident);

p_{is} – probability of occurrence of aviation occurence (incident, accident, catastrophe).

The risk assessment allows classifying occurance of similar events by reducing the level of risk in R_i and using the resulting rank, to determine the order of priority in order to ensure adequate flight safety.

In accordance with Formula 2.1, a risk level can be set at a time interval

$$[t_0 + \Delta t], \tag{2.2}$$

where t_0 – time of occurrence of unfavorable factor;

Δt – the time interval when the crew of the aircraft take measures to eliminate the adverse factors.

In order to assess the level of risk, we will use the flight safety requirements for the occurrence probability of the special situation, and from all the possible risk factors we will consider only technical functional failure (Fig. 2.2).

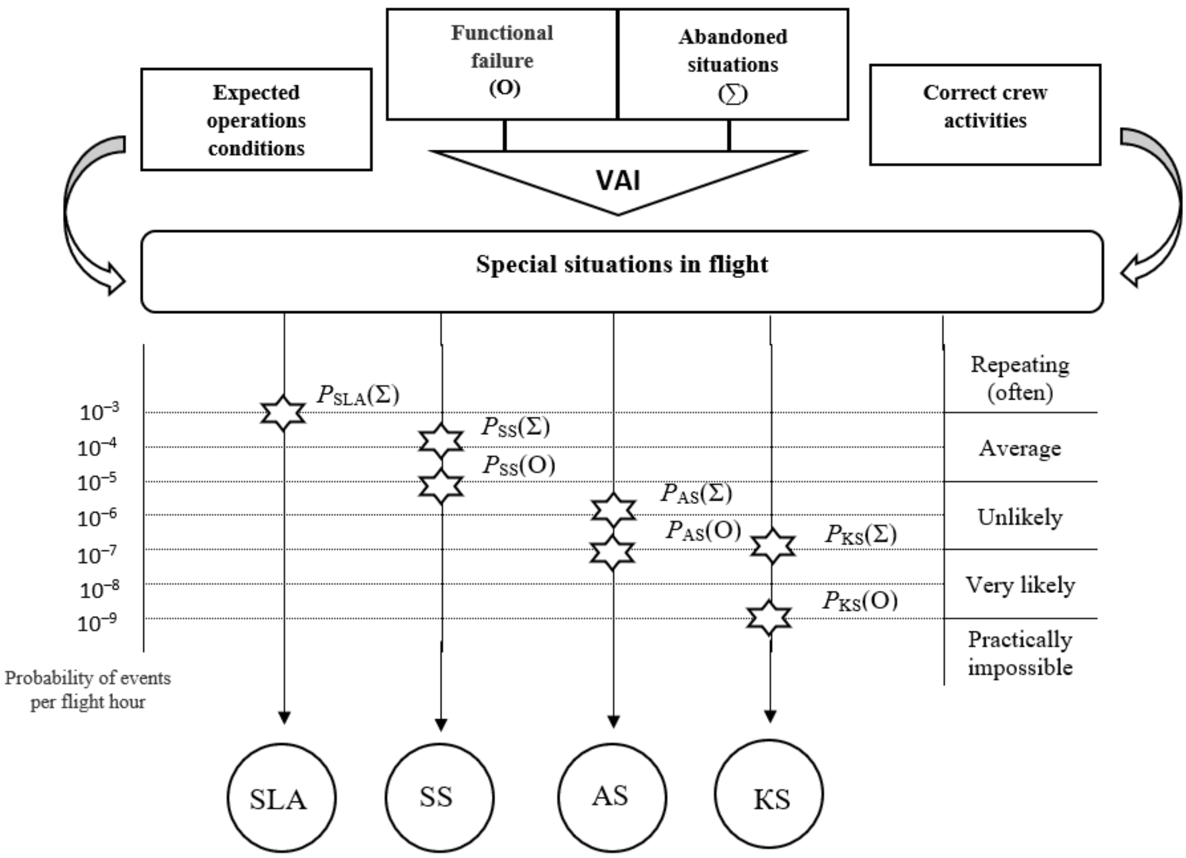


Fig. 2.2. Flight safety requirements for non-refoulement work ability of the aircraft (operational safety).

When categorizing the adverse events (incidents) of a flight in accordance with flight safety requirements and assuming a probability of catastrophe as 1, we obtain

$$Q_i = q_i p_{is}, \tag{2.3}$$

and

$$p_{is} = \frac{n_i}{T}, \tag{2.4}$$

where Q_i – risk situation;

i – index of special situation during the flight;

q_i – situation probability;

p_{is} – probability of occurrence of aviation occurence (incident, accident, catastrophe);

n_i – the number of events of a given type within a specified time interval;

T – observable time period.

The risk assessment for one flight hour or one flight is determined according to the following formula:

$$\frac{R}{T} = Q_{KS} + Q_{AS} + Q_{SS} + Q_{SLA} + Q_{SLA} = \sum \frac{q_i p_{is}}{T}. \tag{2.5}$$

Figure 1.4 shows the repeatability pyramid of the occurrences during the flight.

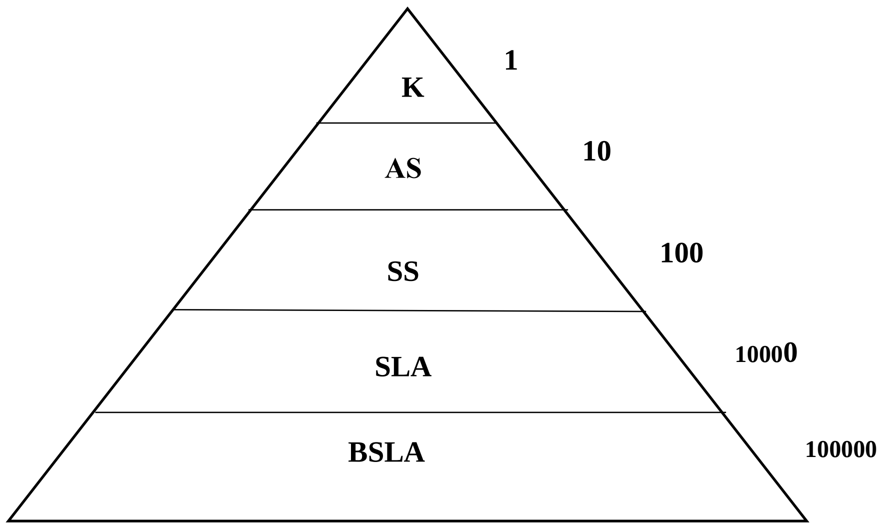


Fig. 2.3. The repeatability pyramid of the occurrences during the flight.

KS – catastrophic situations; AS – emergency situations; SS – difficult situations; SLA – complicated flight conditions; BSLA – an event without complicated flight conditions.

In order to assess the level of risk, we must analyze all special situations.

Then the level of risk R will be the sum of the specific situation risks that may arise as a result of the special situations included in Fig. 2.3. using weight coefficients λ_i.

For the small and medium size airlines, the relative flight safety indicator can be calculated with sufficient accuracy using the following formula:

$$K = \frac{N_{\text{NG}}}{A}, \tag{2.6}$$

where N_{NG} is the total number of negative events classified in the normative documents, as well as the violations of existing irregularities and standard (specified) parameters, equipment failures and other events not falling within the pyramid events shown in Fig. 2.3, such as passengers, flights, landings, etc.; and A is aircraft flown hours during the calculated period of time.

Conditon of coefficient K is $k < 1$.

In order to increase the relative level of flight safety, we introduce the criterion scale factor

$$M = 10^5. \tag{2.7}$$

N_{NG} is calculated according to the following formula:

$$N_{\text{NG}} = K_1 N_{\text{KS}} + K_2 N_{\text{AS}} + K_3 N_{\text{SS}} + K_4 N_{\text{SLA}} + K_5 N_{\text{BSLA}} = \sum K_i N_i, \tag{2.8}$$

where K_1, K_2, K_3, K_4, K_5 – the weight factor of negative events.

As the negative events differ not only by the risk factors of their consequences, but also the frequency of their occurrence, the coefficients of the indexes are determined using the expert method

$$K_1 = 0.5;\ K_2 = 0.3;\ K_3 = 0.1;\ K_4 = 0.05;\ K_5 = 0.005. \tag{2.9}$$

Putting values from Equations 2.8 and 2.9 into Equation 2.6, we obtain

$$K = \left(0.5N_{\text{KS}} + 0.3N_{\text{AS}} + 0.1N_{\text{SS}} + 0.005N_{\text{BSLA}}\right)\frac{10^5}{A}. \tag{2.10}$$

The relative flight safety index for the analyzed period is determined by formula

$$K = \left(\frac{1 - N_{\text{NG}}}{A}\right) \cdot 100,\ \%. \tag{2.11}$$

The relative flight safety index K at a given time period is simple and its acquisition is easy to understand.

3. DEVELOPMENT OF A QUALITY MODEL TAKING INTO ACCOUNT THE LEVEL OF FLIGHT SAFETY

In qualitative terms, the quality level is relative. This is the result of the evaluation of the object and the determination of its quality indicators by the normative (elaton) values.

Quality assessment is a special type of management aimed to assess objects according to their values. The quality of a product is evaluated on the basis of a quantitative assessment of its properties. Modern science and practice have developed a system for evaluating the quantitative qualities of a product that provides quality indicators.

The quality indicators (for an object) can, in relation to their characteristics, be:

- separate;
- complex.

Separate quality indicators are quality indicators that apply to only one of the properties of the object.

Complex quality indicators are quality indicators that relate to several properties of the object.

3.1. Interaction of airline's quality model with quantitative performance

When developing the model, we use the following concepts:

- W_{tkm} is absolute volume of air transportation, the volume of air transport over a specified period of time, determined by the number of passengers and the load at a given distance (passengers-km, tons-km);
- W_{tkm_ef} is effective volume of air transportation, the volume of air transport, which is characterized by a specific quality level, expressed in terms of quality indicators.

Then, the interaction of airline's quality model with the airline's quantitative performance can be represented as the following function:

$$W_{tkm\_ef} = F(W_{tkm}, K_1, K_2, K_3, \dots, K_m, a_1, a_2, a_3, \dots, a_n). \quad (3.1)$$

where W_{tkm_ef} – effective volume of air transportation;

W_{tkm} – absolute volume of air transportation;

$K_1, K_2, K_3, \dots, K_m$ – complex social significant performance indicators of the airline's performance: flight safety level, passenger and cargo delivery speed, regularity, passenger and customer service levels, etc.;

a_1, a_2, a_3, a_n – individual quality indicators for each indicator (technical, economic).

All indicators are infinite. All the indicators that are used in qualitative analysis using the comparator method can be included in one overall quality indicator. Let us denote it as K_t (its infinite value). Then, the effective amount of aircraft traffic W_{tkm_ef} can be obtained by multiplying the absolute volume of aircraft traffic over a given period W_{tkm} with the overall complex quality indictor K_t. Then, the airline's quality model, in conjunction with the airline's quantitative performance, will be as follows:

$$W_{\text{tkm\_ef}} = W_{\text{tkm}} K_{\text{t}}. \quad (3.2)$$

Overall quality indicator K_t is the quantitative assessment of the airline for a specified period of time. This includes several non-standard indicators ($K_1, K_2, K_3, \ldots, K_m, a_1, a_2, a_3, \ldots a_n$) where the most important of them is the flight safety K_1. By dividing the total amount of airlift with total costs, we obtain the integral quality index K_{in}, and obtain the interoperability model in another way:

$$K_{\text{in}} = \frac{W_{\text{tkm\_ef}}}{\sum C}, \quad (3.3)$$

where $\sum C$ is expenses (costs) for the carriage of aircraft during the certain period.

In practice, it is important to determine at the expense of which K_{in} changes: the high cost reduction at constant or reduced costs. Could cost growth be driven by a higher growth rate than quality growth?

In addition, there may be cases where one and the same K_{in} value can be obtained with different individual parameters that are included in model calculations.

The values of K_{in} and K_{t} are functionally dependent:

$$K_{\text{in}} = f\left(K_{\text{t}}\right). \quad (3.4)$$

This relationship is not determined.

In this way, we have obtained a theoretical model (3.1), which determines the interaction between flight safety as a quality and economic indicator not only as static but also in a dynamic state.

Using Eequations 3.2, 3.3, and 3.4, we can show the interconnection between the volume of air transport and the quality characteristics of each air transport product, taking into account the cost of provided service and the production costs.

Taking into account only the flight safety indicator characterizing the aircraft product, the quality of the air transport (K_{in}) will be characterized by the following ratio:

$$K_{\text{in}} = f\left(W_{\text{tkm\_ef}}, K_1, \sum C\right), \quad (3.5)$$

where K_1 – flight safety level;

C – expenses (costs) for the carriage of aircraft during the certain period;

$W_{\text{tkm\_ef}}$ – effective volume of air transportation;

K_{in} – the quality of air transport.

3.2. Development of a model of changes of indicators based on the process approach

The structure of the airline is dynamic. The results of the airline’s operations, as well as the factors affecting it, are in constant motion.

Therefore, the question arises as to what should the ratio of speed of changes of the quality model (3.3), for the airline to carry out airlift services to the maximum satisfaction of consumers with aviation services provided, and for the airline be efficient and competitive in the aviation sector.

This task is the main objective of the airline's integrated management system and is based on a process approach.

In order to achieve the goal of our research, the author will build on the following.

The model (3.3) can be represented as a set of three processes, resulting in a constantly changing variety of factors characterizing the operation of the airline.

These processes are:

- D_1 – the process of obtaining final results, characterized by the dynamics of changes in air traffic volume and changes in the quality of transport services;
- D_2 – changes in indicators characterizing the infrastructure of the company and investments in order to ensure its proper maintenance and improve the infrastructure of the airline (depreciation of fixed assets, modernization and purchase of aircraft fleet, etc.);
- D_3 – operation process characterized by dynamics of consumption of consumable materials and their costs (fuel and lubricants, wear and tear of aircraft and equipment, their maintenance and repair, etc., dynamics of personnel salary costs).

Indicators D_1, D_2, D_3 are inherently complex quality indicators, which are mathematically represented in formula

$$D = \sum_{i=1}^{n} (k_i q_i), \qquad (3.6)$$

where D is complex quality indicator; k_i is i-th factor weight index; and q_i is relative quality indicator.

3.3. Ranking of indicators describing the airline's operating mode for a certain period of time

Based on the process approach to address flight safety issues and apply quantitative assessment of the organization's activities and results, based on the ISO 9001:2015 methodologies, and based on the principle that only what can be measured can be managed using a universal mathematical tool:

$$D_i = \sum_{(i)} a_i k_i, \qquad (3.7)$$

where D_i is complex indicator;
a_i is separate quality indicator;
k_i is weight ratio.

This weighting factor is calculated taking into account the correlation coefficient, the Lagrange partial multiplier method, or, if there is insufficient statistical material, it is determined experimentally.

Analyzing the dynamics of changes in processes D_1, D_2, D_3 in a limited time interval and based on the experience of the airline, we assume that the ratio that best suits the airline is:

$$D_1 > D_2 > D_3 D_1 > D_2 > D_3. \quad (3.8)$$

The growth rate of $D_1 > D_2 > D_3$ indicators during the operation of the airline implies constant and proportional increase (decrease) in indicators, contributing to the achievement of end-of-life results, which increases the airline's efficiency and competitiveness. Thus, the ratio $D_1 > D_2 > D_3$ is the standard, the airline's development benchmark.

Then the ratio of the actual value of the indicator to the normative by its very nature will be the quality indicator of the airline's performance.

The goal of the company is to ensure that the quality of the quality indicators exceeds the growth rate of work, but at the same time the growth of operating costs and capital investment must be lower than the increase in the quality indicators and the amount of work. This relationship is ensured by sound structural and investment policies. The essence of structural policy is that the dynamics and structure of capital investment is consistent with the structure and dynamics of the changes in the end result. If the rate of change in qualitative indicators decreases, a causality analysis is conducted, i.e. the cause of such a downturn is identified and appropriate investments are made in that area, which is the reason for the decline in quality.

If there is information on the behavior of the indicators, on the demand for transportation and resources in the company, on the technical basis of the materials, certain requirements (certification) for personnel, and if there is information on the assessment of the transport infrastructure and technical equipment, then it is possible to plan in the long term the operation of the company and its technical basis on which the financial basis is based in order to prevent possible causes of the decrease in the quality of transport services, i.e. improving flight safety, which in turn guarantees the airline's competitiveness in the airline industry.

Thus, the developed indicator and model system fairly reflects the relationship between flight safety and economy with the main economic categories and aircraft manufacturing factors.

3.4. Methodology to determine quality, taking into account the level of flight safety, based on factual analysis

3.4.1. Ranking of indicators describing the airline's operating mode for a certain period of time

In the operation of the airline, at every moment (in dynamics), interactions of various indicators take place: material, human factor, economic, as well as indicators characterizing external climatic and natural conditions, etc.

At a given time, a certain set of indicators corresponds to the relevant performance of the airline: the volume of traffic and its quality are the level of flight safety, which is the priority of the airline.

To determine the relationship between the flight safety level and the airline's economic performance, we will use an indicator analysis based on the ranking of indicators.

If all the indicators related to the operation of the airline are ranked in descending order of the relevant period (year, quarter, month, etc.), we obtain several indicators that characterize the airline's operating mode for a certain period of time.

These benchmarks make it possible to detect correlation between undesirable indicators of change, for example, the increase in air transport accidents is higher than the increase in air traffic, the increase in aircraft maintenance and repair costs is higher than the increase in the repair of aircraft crew.

Ranking is very informative.

In addition, comparing the actual and the standard (preferred) row according to the diversity of the ranking allows to quantify the actual degree of compliance of the company with the benchmark and to find out the correlations between the interconnected indicators.

According to the adopted model, we have the following set of factors and performance indicators for the airline with the following meanings.

1. Operatation results.

1.1. Changes in safety indicators reflect the fluctuation of the airline's safety level over the selected time interval.

1.2. The changes of airline's final results reflect the volatility of air services during the certain period.

2. Infrastructure.

2.1. The dynamics of airline investment in the airline reflects the dynamics of change in indicators that characterize quantitative and qualitative changes in aircraft: renewal, functional safety, design, maintenance, etc.

2.2 The dynamics of airline investment (capital investment) changes reflect the dynamics of material technical indicators that characterize the quantitative and qualitative changes of airline's infrastructure: aircraft technical, flight and commercial operation objects and assets.

3. Operating costs.

The dynamics of group indicators, which are characterized by changes in aircraft operating conditions, are easily estimated by analyzing the dynamic monetary costs of changes in indicators.

In addition, it must be taken into account that each airline will have its own characteristics.

For our research purposes, we use the following items of expenditure (this choice is not fundamental – there may also be another set of indicators to assess the dynamics of the indicators that characterize changes in operating factors).

1. Fuels and lubricants.
2. Aircraft amortization (amortization).
3. Aircraft maintenance and repair.
4. Flight crew salary.
5. Salary of engineering personnel.
6. Salary of other personnel.
7. Unforeseen expenses.
8. Total maintenance costs.

In mathematical terms, the dynamics of changes in these variables is the derivative of each of them in $d_{ij,}$where i is process index; and j is relevant process indicator index.

In order to implement these rules in the airline's operational practice, aircraft types must prioritize the development of indicators for each of these factor groups, i.e., benchmarking the indicators.

3.4.2. Development of standard (benchmark) rating indicators

In the first set of indicators, where D_1 represents the end results, there are two factors: K_t – safety factor and W – air volume (passengers or tonne-km).

The flight safety indicator has an unconditional priority over the production volume indicator. In other words, the dynamics of the flight safety level indicator d_{11} (derivative) must exceed the increase in the volume of transport, d_{12}:

$$d_{11} > d_{12} \; . \qquad (3.9)$$

This means that d_{11} is in the first place of the ranking and d_{12} is in the second place. The second group of indicators D_2, which determines the diversity of material factors of the company's infrastructure, also included two indicators: total investment in aircraft, $F_{gk}(d_{22})$, and infrastructure, $F(d_{21})$.

Experience has shown that the development of the material base in civil aviation now lags behind the level of aircraft development.

Taking into account this fact, we will establish the following regulatory correlation between investment growth dynamics in infrastructure and the fleet of aircraft, targeting companies in order to eliminate this disproportion in the development of the technical material base for companies:

$$d_{21} > d_{22}. \qquad (3.10)$$

This means that in the third place is d_{21}, and in the second is d_{22}.

The third group of indicators is D_3, which reflects the aircraft operating conditions obtained by analyzing the parameters regulated by various external and internal documents (procedures, instructions, etc.), as well as statistics for the operation of the airline for several years.

Thus, based on the logical conclusions and the analysis of operating costs, a normative ranking was obtained, which consists of 12 indicators (Table 3.1).

Table 3.1

Ranking of Indicators

Factor groups	**Factor subgroups**	**Indicators**	**Ranks**
D_1	1.1	Flight safety, d_{11}	1
	1.2	Volume of air transportation (passengers-km), d_{12}	2
D_2	2.1	Investment in infrastructure, d_{21}	3
	2.2	Investment in aircraft, d_{22}	4
D_3	3.1	Fuels and lubricants, d_{31}	5
	3.2	Aircraft amortization (amortization), d_{32}	6
	3.3	Aircraft maintenance and repair, d_{33}	7
	3.4	Flight crew salary, d_{34}	8
	3.5	Salary of engineering personnel, d_{35}	9
	3.6	Salary of other personnel, d_{36}	10
	3.7	Unforeseen expenses, d_{37}	11
	3.8	Total maintenance costs, d_{38}	12

3.4.3. Development of a methodology to assess the differences between actual and normative indicators

In order to quantify and reflect the differences between the actual and the standard (benchmark) ranking, in the mathematical statistics a ranking correlation is used, whose value in this case is an internal characteristic, since it reflects the effect of the change in the element (or indicator) of each system on the final result. Therefore, its value will be, by necessity, the quality of the airline or the quality of the work performed, taking into account the level of flight safety.

We denote this factor as K_τ. The following expression can be used to calculate the correlation coefficient (work quality):

$$K_\tau = 1 - \frac{6\sum_{L=1}^{n} y^2}{n\left(n^2 - 1\right)}. \qquad (3.11)$$

Calculation sequance of K_τ is as follows.

1. Each indicator has a difference between its place in the normative and actual queue:

$$Y = 1 - X_i, \qquad (3.12)$$

where $i = 1, 2, \ldots, n$;

Y – the difference between the ranking and the i-th position of the indicator;

i – indicator’s place in the series of normative rank;

X_i – actual place in the ranking queue;

n – the number of indicators included in the analysis.

2. For each indicator, the square of the difference (deviation) is calculated between the ranking and the actual place, i.e. it is calculated in Y^2.

The final step is to compare the variations of different indicators over time to compare the movement of a particular indicator with the movement of the first indicator. And this, in turn, is the index of the change (movement) of that indicator. In addition, as a limiting factor, it is advisable not to take into account the maximum value of the actual but of the analyzed period d_{max}.

The next step is to rank the indicators in line with the index value.

Based on the nature of the process being studied, the flight safety change (movement) indicator should grow faster than all other indices.

Excluding aircraft from operation, indicators become negative (the requirement to "grow to the first" means "to fall to the last").

In any case, the flight safety indicator should exceed the other indicators by absolute value:

$$a_i > |a_i|. \quad (3.13)$$

If d_i obtains a negative value, then the flight safety indicator must be assigned the last place in the actual rank. If accidents have not occurred in the airline or the aircraft under investigation, a methodology for assessing flight safety should be developed, taking into account the deviations in the operations of departments and specialists that have the least impact on flight safety.

The calculation of the coefficient $K_τ$, which characterizes the airline's quality of operation in terms of flight safety, is easy to be carried out using Table 3.2.

Table 3.2

Calculation of Coefficient $K_τ$

Factor groups	Factor subgroups	Indicators	Actual movement (change) indicator	Benchmark score	Deviation Y	Divergence square Y^2
D_1	1.1	d_{11}	–	1	–	–
	1.2	d_{12}	–	2	–	–
D_2	2.1	d_{21}	–	3	–	–
	2.2	d_{22}	–	4	–	–
D_3	3.1	d_{31}	–	It is determined by hourly running costs for the type of aircraft and the type of transport		–
	3.2	d_{32}	–			–
	3.3	d_{33}	–			–
	3.4	d_{34}	–			–
	3.5	d_{35}	–			–
	3.6	d_{36}	–			–
	3.7	d_{37}	–			–
	3.8	d_{38}	–			–

4. APPROBATION OF PROPOSED METHODOLOGY BASED ON “AIRLINES” LTD. DATA

4.1. Airline’s general description

Approbation of the proposed method was carried out based on the data of the airline “Airlines” Ltd.

All initial data for quantifying the relationship between the level of flight safety and economic factors are taken from the Airline Information Management System (AIMS), which, as mentioned before, takes into account and retains all the data on the hazards and adverse occurrences of the flight that are required for analysis.

These data are:

- accident and incident investigation reports, flight data monitoring (FDM) and their results; individual (or anonymous) flight incident reports that include special situations during the flight, including the causes of their occurrence, as well as the flight stages in which they occurred; audit results; the airline’s relevant departmental processes and airline personnel mistakes;
- data on the volume of work to be performed:
  - flight hours of the aircraft;
  - number of flights;
  - the number of passengers and cargo transported;
- data describing the operating conditions of the airplane, such as the state of the external environment (weather, ornithological situation, traffic volume, etc.).

All IRS data are collected in a differentiated manner according to aircraft type, class, causes of danger, event types, flight stages, etc.

The study was based on the statistics of one type of Airbus A320 aircraft and their performance over the period 2011–2014.

The result of all the analyzed indicators compared with the movement of safety indicators over the years is shown in Table 4.1.

As we can see, the dynamics of changes in indicators indicates a disproportionate effect of the airline’s operations. Some indicators develop in the normative direction, while others are in contrast to the norm.

This led to fluctuations in the flight safety level, both for better (ascending) and for the worse (downward) (Table 4.1). The study of changes of the dynamics of indicators allows us to obtain important information on the extent to which the proportions of changes in economic indicators have ensured the quality of these transport services.

A decrease in the flight safety level (negative values of the index) can lead primarily to disproportion in the investment distribution between the infrastructure of the airline and the aircraft fleet.

During air transport it is a cost increase for groups 3.3 to 3.8 (3.3 – “Maintenance and repair of aircraft”, 3.4 – “Flight crew salary”, 3.5 – “Engineers’ salary”, 3.6 – “Other employees’ salary", 3.8 – "Total maintenance costs"), i.e. deviations in dynamic ratios d_{21} and d_{22} resulted from excessive expenditure growth for the indicators d_{35}, d_{36}, d_{38}, which is related to the level of flight safety due to the fact that in 2011–2014 there were quite a lot of incidents due to technical reasons.

Table 4.1

Calculation Results

Factor groups	Factor subgroups	Year	Normative indicator rank	Actual indicator rank	Deviation	Divergence square	Year	Normative indicator rank	Actual indicator rank	Deviaion	Divergence square
		Years 2011–2012					Years 2013–2014				
D_1	1.1	2011	1	12	–11	121	2013	1	12	–11	121
		2012	1	11	–10	100	2014	1	12	–11	121
	1.2	2011	2	7	–5	25	2013	2	6	–4	16
		2012	2	7	–5	25	2014	2	5	–3	9
D_2	2.1	2011	3	9	–6	36	2013	3	5	–2	4
		2012	3	9	–6	36	2014	3	9	–6	36
	2.2	2011	4	11	–7	49	2013	4	1	3	9
		2012	4	12	–8	64	2014	4	10	–6	36
D_3	3.1	2011	5	8	–3	9	2013	5	9	–4	16
		2012	5	8	–3	9	2014	5	6	–1	1
	3.2	2011	6	6	0	0	2013	6	4	2	4
		2012	6	5	1	1	2014	6	4	2	4
	3.3	2011	7	3	4	16	2013	7	2	5	25
		2012	7	2	5	25	2014	7	3	4	16
	3.4	2011	8	2	6	36	2013	8	10	–2	4
		2012	8	10	–2	4	2014	8	11	–3	9
	3.5	2011	9	4	5	25	2013	9	8	1	1
		2012	9	3	6	36	2014	9	8	1	1
	3.6	2011	10	10	0	0	2013	10	3	7	49
		2012	10	6	4	16	2014	10	7	3	9
	3.7	2011	11	1	10	100	2013	11	1	10	100
		2012	11	1	10	100	2014	11	1	10	100
	3.8	2011	12	5	7	49	2013	12	7	5	25
		2012	12	4	8	64	2014	12	2	10	100

As seen from Table 4.1, it is not necessary to consider economic conditions during the calculation period in this airline.

Therefore, in 2011 and 2012, the level of flight safety ranks 12 and 11, respectively.

In 2013, it ranked 12, but was 12 again in the following year. This can be explained by the fact that investments in the aircraft park (2.2 – "Investments in the aircraft park") increased in 2011 and 2012, but flight safety was decreasing.

However, in 2013, this indicator is in line with the normative, and the indicator characterizing flight crew salary (3.4 – "Flight crew salary") is higher than the normative one. All this provided a higher level of flight safety this year, which confirms the correctness of the proposed model accordingly.

4.2. Development of the airline's operational planning model, taking into account the mechanism of relations between economic indicators and the level of flight safety

4.2.1. Mechanism of relations between the level of flight safety and the airline's economic performance

As mentioned before, economic indicators are considered to be of particular importance, as they are affecting the processes of the airline company in relation to the level of flight safety.

This influential economic indicator is part of the transport product quality model, taking into account flight safety.

Economic indicators are the conditions, the environment, the working environment in which this indicator operates.

Indicators reflect the minimum conditions necessary to fulfill the transport process (production environment, working conditions, work itself) characterized by complex factors such as D_2 process and operating costs – process D_3.

Therefore, economic indicators determine simultaneous effects on a number of factors, indicating the direction, type and impact of the transport process.

Information on economic indicators is given instead of the absolute values of these indicators, but with indicators of change that have a fairly defined economic interpretation. Based on calculations (Table 4.1), we can now generalize the mechanism between flight safety and economic performance.

The use of this mechanism in planning investments in the infrastructure of an airline and in an aircraft park will create the optimal economic ratios described by the model (3.3), which is a prerequisite for improving flight safety.

The higher the level of work quality, the closer is the actual proportion of economic indicators in the air transport process to the norm $D_1 > D_2 > D_3$, i.e. the greater the correlation between them, the higher is the level of flight safety for such aircraft.

The study of dynamics of change in indicators d_{ij} allows to obtain important information on the extent to which the level of security has been ensured, due to which the ratio of economic indicators has changed. The d_{11} decrease can be caused mainly by the imbalance in the distribution of investment between the infrastructure of the airline and the aircraft fleet. This is a typical tendency for airlines when the growth rate of airline infrastructure investment lags behind the growth rate of investment in aircraft fleets. Disproportion in the investment distribution between the airline's infrastructure and the aircraft park in the air transport process is usually caused by the process cost group D_3 (d_{3j}) – higher growth rate of operating costs.

These reasons relate, firstly, to the lack of aircraft maintenance, secondly, to the lack of staff qualification, interest (motivation) in work, and therefore the number of adverse events ocurring due to technical reasons, as a result of staff activities or inactivity, tends to grow.

In these circumstances, the flight crew activities become more complicated, which can lead to making mistakes.

In turn, this process leads to differences in the development of indicators for the technical basis of materials and indicators that characterize the airline's operational activities, or the differences between the growth rates of investment in infrastructure and the fleet of aircraft, as well as operating costs where there is an investment deficit.

Ultimately, this leads to the fact that flight safety deviations caused by lack of investment, poor quality and disproportionate distribution are not compensated for by the aircraft operation process and transferred to the transportation along with the flight safety shuffle that is tied to the actions of the airline staff product or poses a potential risk to the occurrence of flight incident preconditions.

In this case, there is a tendency for the safety of flights to decrease, which reduces the quality of air transport. The competitiveness of airline will also decrease.

Other types of trends in the development stages of the airline may be related to the level of flight safety d_{11} and the economic factors D_{ij}. This is reflected in the author's calculations.

At the same time, the regularity of certain interactions between factors of d_{ij} is clearly visible, which makes it possible to develop an operational impact model in the airline's integrated management system.

4.2.2. Development of the operational impact model of the airline's integrated management system

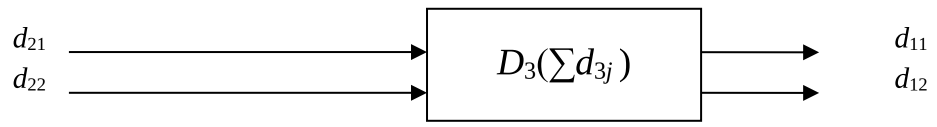
Interpretation of the interrelationships of different types of d_{ij} in general can be obtained on the basis of the model of airline's operating process (3.3) described before.

The introduction of the model (start) will be the structure and dynamics of the investment D_2 (d_{21}, d_{22}). The components of the model will be:

- dynamics of operating cost changes – process D_3 ($\sum d_{3j}$);
- dynamis of output indicators – process D_1 (d_{11}, d_{12}).

The model structure is shown in Fig. 4.1.

No.	Entrance structure and dynamics			Operating cost trends



No.	Entrance structure and dynamics		No.	Operating cost trends
1	$d_{21} > d_{22}$	$\uparrow d_{\Sigma d3j}$	1	$\uparrow d_{11} < \uparrow d_{12}$
2			2	$\uparrow d_{11} > \uparrow d_{12}$
3			3	$\downarrow d_{11} \quad \uparrow d_{12}$
4			4	$\downarrow d_{11} \quad \uparrow d_{12}$
5			5	$\uparrow d_{11} \quad \downarrow d_{12}$
6		$\downarrow d_{\Sigma d3j}$	6	$\uparrow d_{11} < \uparrow d_{12}$
7			**7**	$\uparrow d_{11} > \uparrow d_{12}$
8			8	$\downarrow d_{11} \quad \downarrow d_{12}$
9			9	$\downarrow d_{11} \quad \downarrow d_{12}$
10			10	$\downarrow d_{11} \quad \uparrow d_{12}$
11	$d_{21} << d_{22}$	$\uparrow d_{\Sigma d3j}$	11	$\uparrow d_{11} < \uparrow d_{12}$
12			12	$\uparrow d_{11} > \uparrow d_{12}$
13			13	$\uparrow d_{11} \quad \downarrow d_{12}$
14			14	$\downarrow d_{11} \quad \uparrow d_{12}$
15			15	$\downarrow d_{11} \quad \downarrow d_{12}$
16		$\downarrow d_{\Sigma d3j}$	16	$\uparrow d_{11} < \uparrow d_{12}$
17			17	$\uparrow d_{11} > \uparrow d_{12}$
18			18	$\uparrow d_{11} \quad \uparrow d_{12}$
19			19	$\downarrow d_{11} \quad \downarrow d_{12}$
20			20	$\uparrow d_{11} \quad \downarrow d_{12}$

Fig. 4.1. The operational impact model of the airline's integrated management system.

Operating costs tend to increase. In this case, there is a tendency to change the output characteristics of the output (this can be seen from the calculations, see Table 4.1). They allow us to qualitatively evaluate the values of the output parameters. For example, the increase in the level of flight safety, the volume of air travel (passengers-km) tends to increase less than tonne-kilometers (second option).

This shows that the investments are properly distributed. They are focused on systematic work to ensure flight safety. Firstly (more intensively) the technical basis of the materials in the airline is improved, i.e. material conditions are created to improve flight safety, and only then (less intensively) the fleet of aircraft is increased.

But the planned investments are insufficient, they require a large amount of work and material costs. In addition, these investments are clearly not big enough as the trend for the increase in safety level is lower than the trend towards an increase in air traffic.

Given this type of mechanism for linking flight safety to the airline's economic indicators, a company-specific plan should be developed based on an analysis of risk factors that create special situations on the flight aimed at improving the appropriate technical means for servicing aircraft in order to reduce the amount of work and material costs related to their operation.

Operating cost analysis provides guidance for the introduction of the economic regime.

If the level of flight safety tends to increase more than the growth rate of air transport, then in this case, the company's plan should include measures for economic regime.

A more detailed analysis is needed when there is a tendency for the level of flight safety to decrease. The main reason here is that the structure of the airline's infrastructure and measures to improve flight safety do not coincide with the structure of risk factors registered in the information system of integrated management system.

The next five types of connections (6–10) are characterized by the fact that operating costs usually decrease with input dynamics $d_{21} > d_{22}$. Connection type **7** is the most balanced and needs to be used by the airline. When the flight safety level tends to decrease, a factor must be identified which reduces operating costs.

Does it cause damage to improve flight safety processes? A reduction in the effectiveness of a flight safety system may occur.

The next five types of connections are characterized by the fact that the dynamics of investment changes in the infrastructure of an airline surpasses (exceeds) the investment dynamics in the aircraft park $d_{21} < d_{22}$.

This type is most suitable for airline companies purchasing new aircraft. Relationships 16–20 are controversial.

Deviation from the flight safety caused by disproportionate investment in the allocation of the airline's infrastructure and aircraft fleet is not compensated by the corresponding operating costs, i.e. the airline does not take appropriate measures to compensate for the flight safety diversions associated with the growth of the fleet of aircraft.

The most controversial types of interconnections are 18 and 19. The faster these disproportions are eliminated, the faster the optimal economic conditions for an increase in flight safety will be created.

The planned management of the disproportion in the integrated management system should organize an operational model of the production process in the airline (Fig. 4.1).

In order to assess the relationship between flight safety and economic indicators, recommendations should be made for optimal economic conditions in order to increase the flight safety evenly.

4.2.3. Approbation of the developed planning methodology

Approbation of the developed method was carried out on the basis of the described airline. In order to improve flight safety, the airline needs to improve the results of the previous period.

The task is to select the process indicators D_1, D_2 and D_3, which, with limited resources, meet the airline's development requirements to the maximum. In this case, the airline will ensure continuous optimal economic conditions to improve flight safety.

The purpose of the planning is to improve the indicators developed in our study in the period 2011–2014.

The development trends of the i-th index give the average motion indicator $d_i v$, which is defined as the average value obtained in the previous reporting period:

$$d_i v = \frac{\sum_{i=1}^{n} d_i}{n}, \tag{4.1}$$

where d_i – the actual indexes of the movement indicators in the previous calculation period;
n – the number of years in the calculation period.

Next, it is necessary to determine the possible range of changes based on the *i*-th index development trend, using the deviations of the actual index indices (during the analyzed period) from the average indicators:

$$ni = \frac{\sum_{i=1}^{n} | d_i - d_i v |}{n_i}, \tag{4.2}$$

where d_i is fluctuations of *i*-th indicator;
$d_i v$ is the average value of movement of *i*-th index;
n is the number of years in the calculation period.

4.3. Development of quality assessment methodology of an integrated management system and its impact on the competitiveness of the airline

The author's Management Functional Assessment Model (MFAM) has been adapted to the operating conditions of the airline and allows analyzing the airline, identifying its strengths and weaknesses, describing priority enhancement areas, and keeping track of improvements in dynamics. Thus, the proposed model acts as a tool for continuous improvement of the management system.

The model used is based on six key management functions: forecasting / planning, work organization (management), motivation, control, coordination and communication.

The first five management functions correspond to five model assessment criteria and form a management structure, which in turn sets the sixth criterion – communication, which characterizes the relationships in the airline.

The evaluation of the integrated management system of the airline within the framework of this model suggests analysis of five management functions, which is the criterion for model evaluation.

In each of the five criteria, there are five subseries, so the functional management assessment model combines 18 rating categories. The summary and structure of this work criterion is presented in Table 4.2.

Ta

ble 4.2

Characteristics of the Airline's Integrated Management System

No.	Indicators	Indicator characteristics
1.	Provision of information to ensure the operation of the airline	Automation level of management process
		Providing documentation (regulatory basis) for the operation of the airline
		Development level of Airline Information Risk System (IRS)
2.	Organizational level of the airline - operational level	Fuel and lubricants, d_{31}
		Aircraft amortization, d_{32}
		Aircraft maintenance and repair, d_{33}
		Unpredicted expenses, d_{37}
		Total maintenance costs, d_{38}
3.	Organizational and technical level of air transport operations	Fleet renewal level
		Infrastructure and ground equipment renewal in the airline
4.	Protecting the market position (quality level)	Passenger turnover
		Flight regularity
		Flight safety
		The airline's profitability
5.	Employees' Potential	Staff preparation level
		Flight crew salary, d_{34}
		Technical personnel salary, d_{35}
		Other employees' salary, d_{36}

To visualize the evaluation results, we will use the pentagram based on which one can determine the airline's communication profile, which is based on each of the five model assessment criteria (Fig. 4.2).

This approach/method makes it possible to identify the priority directions that are needed to improve the developed integrated management system.

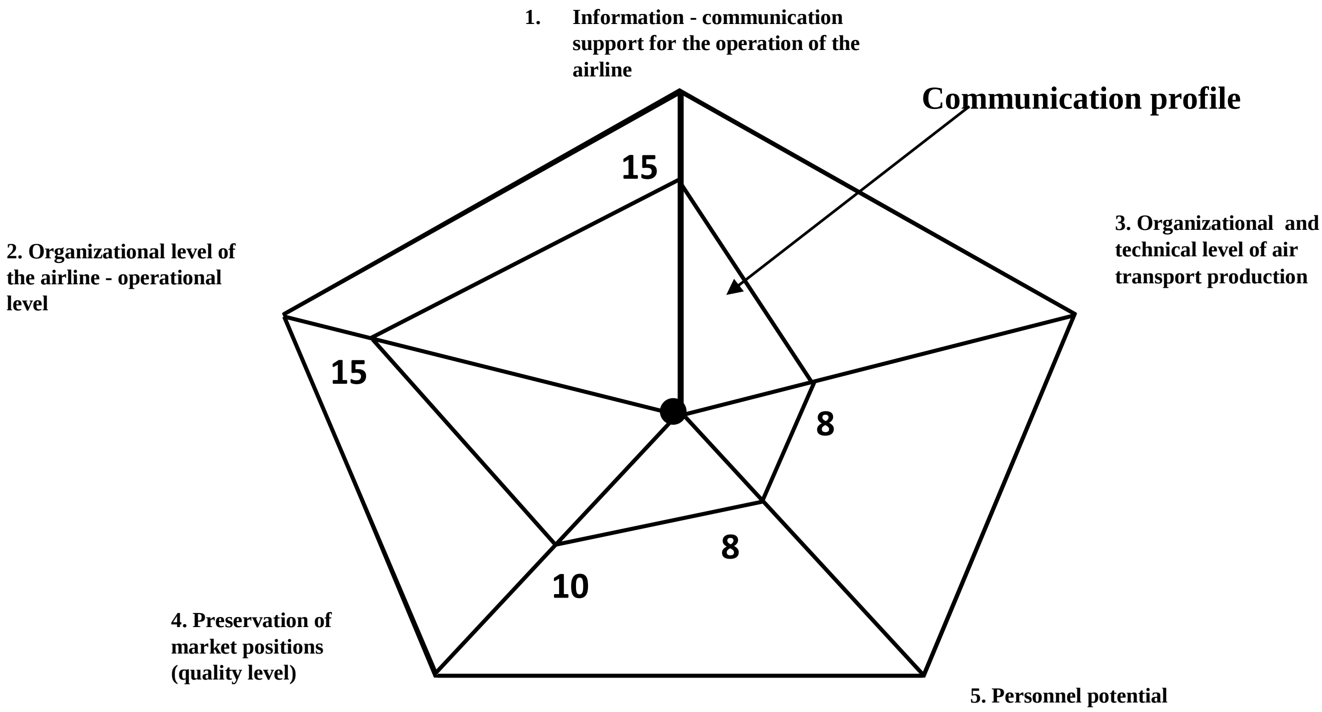


Fig. 4.2. “Airlines” Ltd. Communication profile.

As shown in Fig. 4.2, the company has problems with flight organization level and staffing potential, and these areas of management need detailed analysis and refinement.

It should be borne in mind that the measures taken to improve one of the criteria will affect the others, i.e. the criteria are closely related.

Each time, after the functional evaluation, corrective actions are performed, the previous communication profile is covered with the new one with the aim of determining the efficiency and dynamics of the improvement of the competition management system. Thus, in practice the MFAM functional model introduces the continuous improvement methodology of the airline’s integrated management system.

CONCLUSIONS

1. The concept of airline's flight safety system and a model of its information base have been developed, which is a statistical device intended for gathering and analyzing the data of non-conformities of the departments and personnel of organisation that are related to the airline's main operating results and flight safety status. A quantitative assessment model for flight safety indicators has been developed, which is based on an information base and verified in the airline.
2. A model of interconnection of air transport quality was developed, the main component of which is the level of flight safety with quantitative indicators of the airline. Processes describing the activities of the airline were formulated and based on their analysis the ratio of changes of indicators was obtained in a certain time interval.
3. A methodology for measuring the interaction of the indicators was developed, which determines the relationship between the quality level and the economic indicators of the airline, as well as a system of indicators that describes the activities of the airline during the relevant period and the basic principles of their ranking and the norms of these indicators (benchmarks). A methodology was developed for assessing the difference between actual and normative indicators, as well as criteria for evaluating the flight safety level of the integrated quality management system.
4. Approbation of the developed models, based on the results of the "Airlines" , indicates that the reasons why the actual indicators do not conform with the normative (standard) are sufficiently precise, informative and reliable. It allows the identification of changes in economic conditions and indicators that are associated with a certain reduction in the level of safety of flights. It also allows the following:
   - to identify economic indicators that reduce flight safety;
   - to identify trends in economic indicators that reduce the level of flight safety;
   - to determine economic indicators by changing the relationship between the investments and production costs of transport products, which would improve the level of flight safety.
5. The airline's work planning model has been developed and tested, taking into account the relationship between economic indicators and flight safety, which includes operational implications for the processes of the airline's integrated management system.
6. The study confirmed the theoretically important relationship: the closer the actual figures D_1, D_2, D_3 are in relation to the normative (the higher the correlation between them), the greater is the level of flight safety. The economic nature of this connection is as follows: the more economic indicators are distributed in order to develop the material and technical base (D_2) and the airline's resource allocation and use (D_3), the higher is the quality and flight safety.

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ABBREVIATIONS

ATS – Aviation Transport Systems (Aviācijas Transporta Sistēmas)
ARMS – Aviation Risk Management Solutions (Aviācijas riska pārvaldības risinājumi)
CAA – Civil Aviation Agency (Civilās Aviācijas Aģentūra)
EASA – European Aviation Safety Agency (Eiropas Aviācijas Drošības Aģentūra)
FAA – Federal Aviation Adminstration (Federālās aviācijas administrācija)
FAR – Federal Aviation Requirements (Federālās aviācijas prasības)
FDM – flight data monitoring (lidojuma parametru atšifrēšana)
HFACS – Human Factors Analysis and Classification System (Cilvēka faktoru analīzes un klasifikācijas sistēma)
IATA – International Air Transport Association (Starptautiskā gaisa transporta asociācija)
ICAO – International Civil Aviation Organization (Starptautiskā Civilās Aviācijas Organizācija)
IIS – Integrated Information System (Integrētā informācijas sistēma)
IOSA – IATA Operational Safety Audit (Gaisa kuģa ekspluatācijas drošības audits)
IRS – Information Risk System (Informācijas Risku Sistēma)
ISO – International Organisation for Standardization (Starptautiskā standartizācijas organizācija)
IVS – Integral Management System (Integrālā vadības sistēma)
JAA – Joint Aviation Authority (Apvienoto aviācijas institūcija)
KVS – Quality Management System (Kvalitātes Vadības Sistēma)
Ltd – Limited company
MFAM – Management Functional Assessment Model (Vadības novērtēšanas modelis)
OPC – IATA Operational Comittee (IATA Ekspluatācijas Komiteja)
SMS – Safety Management (Drošības vadības sistēma)