

The scientific-practical basis of the quality of passenger and clientele service at the airport were studied. This was prompted by the need to determine the role of aviation safety (AS) and its impact on the quality and competitiveness of airport services. It was proved that within the framework of the system, quality monitoring is performed in the areas of the service of aviation safety (SAS). As a result of research, a quantitative assessment of the level of aviation safety of the airport, which is the basis for making a relevant management decision in the analysis subsystems, was determined. Management, in this case, implies the system of measures to improve the activities of the SAS.

A procedure for assessing the quality of airport services, which reveals the essence of aviation safety in the system of airport quality management, was devised. The sequence of assessment of the system of aviation safety, reflecting the cost approach, the application of which involves determining the reserves for ensuring aviation safety in the continuous implementation of the quality management system, was proposed.

The share of costs of aviation safety (AS) was determined on the example of three airports by economic elements (the model of criteria for choosing a subject) to determine the cost of ensuring an adequate level of aviation safety.

It was proposed to introduce a comprehensive indicator of the quality of aviation safety for its functional components, which further makes up the integrated indicator of the quality of provided services. As a result of calculations, the amount of payment for aviation safety using adjustment coefficients to counteract the threat of a possible act of unlawful interference (AUI) will increase. This enables an aircraft company to form timely a reserve to prevent or eliminate the consequences of the AUI by including the aviation safety fee in the total cost of air transport services

Keywords: *system of aviation safety (SAS), act of unlawful interference (AUI), management of airport service quality*

CONSTRUCTING A SYSTEM OF INTEGRATED MANAGEMENT OF AVIATION SAFETY AS A KEY ELEMENT OF AIRPORT SERVICE QUALITY

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1. Introduction

At different levels of functional performance of airport services, special attention is paid to the quality of these services. However, modern conditions and compliance with the ISO standards determine the improvement or construction of a new system of long-term cooperation with consumers of airport products in order to increase the level of competitiveness in the air transportation market. An important factor influencing the quality of passenger and clientele service is the organization of the system of aviation safety of an airport. That is why there is a need for the airport authorities to constantly increase the level of aviation safety and strengthen its relationship with each element of the system of quality management. Thus, the implementation of the integration processes of the system of airport aviation safety based on the system of quality management is relevant and will enable airports to be competitive in the aviation services market.

2. Literature review and problem statement

Paper [1] explores a complex integrated concept of “civil aviation safety” and its components. Based on scientific analysis of the current legislation, international law, and scientific literature, the authors proposed their definition of these concepts. The national legislation does not define the concept of “civil aviation safety”, hereinafter «CA safety”, which is used in regulations without explaining the content. There is the term “aviation safety”, but the regulatory documents do not explain its direct content either.

That is why the proposed basic aspects give only the concept of “aviation safety” in two aspects: as a state of aviation safety security against illegal interference in the activities of the aviation industry, or as a set of measures for the AS. The author excludes the mandatory component consisting of human and material resources intended to protect civil aviation from acts of unlawful interference.

The authors of study [2] who analyzed the aviation safety system with the help of fractal and statistical tools drew attention to the assessment of the level of aviation safety and the search for new approaches to the analysis of the state of aviation safety security. The co-authors of scientific work [3] proposed theoretical approaches to measuring safety levels using the test of sequence factor. However, these studies left apart of the problem of a strategic vision of the management of aviation safety security unresolved. The above publications do not consider the current level of ensuring the safety of air transport directly by the method of integrated evaluation.

Paper [4] discusses the development of modern aviation security by improving the aspects of different levels of aviation safety in order to prevent interference in the operation of airports. The results of research into the introduction of modern technical means of aviation safety reflect the effectiveness of application, but do not solve the problem of ensuring comprehensive integrated safety security.

A significant increase in the safety of the site and the transition from the tactics of rapid response to the strategy of threat prevention, which creates preconditions for improving efficiency in the SAS operation is considered in paper [5]. In this paper, the author emphasizes the additional economic effect of the safety system and draws the attention of the authorities of a site to management issues. However, he does not emphasize that the issue of managing an integrated complex of technical facilities should be considered not only in the plane of functional management, as well as the vision in the area of management of integration parameters, where the system of aviation safety must be adaptive and management must be situational.

The author of paper [6] argues that the experience of recent decades shows the need for the smooth functioning of complex systems. This, in turn, requires improvement of decision-making methods for a prompt response and resuming activities under unstable conditions at all levels of management system. This problem is partly reflected in the initiative of the International Civil Aviation Organization (ICAO) in the field of safety and stated as “the development of an effective response to the violation of the aviation system created by natural disasters, conflicts or other causes” [7].

Scientists approach aviation safety assessment from different points. The authors of paper [8] consider aviation safety and its threats as part of the air transportation system, as well as management of “vulnerability”-associated risks.

Another variation of approaches to assessing the level of aviation safety of an airport was described by the authors in research [9]. Aviation safety in modern systems is ensured based on the organizational and regulatory principle of safety management, which does involve measuring the safety level in quantitative terms. In the paper, the authors express their thoughts on the quantitative reflection of the state of the protection object from the point of view of aviation security and call it “vulnerability”, which shows the degree of safety of transport infrastructure objects. Assessment of “vulnerability” is defined as a degree of compliance of the protected characteristics with the established requirements.

Optimization of the process of aviation safety management is associated with certain parameters of the studied object, the quantitative reflection of which in the dynamics of changes under the influence of external and internal factors remains within the permissible boundaries of an object in terms of its functioning.

According to the authors of [10], the situation with the dynamics of integrated indices and parameters of the AUI components demonstrates a general rapid decrease in an institutional and managerial capacity. Ensuring the desired level of aviation safety is reflected in the fundamental national interests and economy of each country.

Systemic studies make it possible to assert that in this case the state of the protection object can be considered as its certain characteristic related to an uneven, heterogeneous, and unstable environment that ensures the protection of this object.

It should also be noted that quality plays an important role. The advantages include enhanced safety culture, a documented systemic approach to ensuring aviation safety. The activity of an airport is evaluated not by the final “product”, but by the level of service of this “product” by ensuring safety, regularity, punctuality, reliability, throughput, and the appropriate quality standard. In this context, it can be considered as the level of protection of an object from unauthorized interference in its work. In this case, the quality of the totality of the airport protection facilities determines the degree of its safety and is an assessment of “vulnerability”.

The authors of research [11] analyzed the impact of perceived time of waiting for the activities of the airport aviation safety service, with the help of psychological and emotional reactions of passengers. As a result of performed simulation of structural equations, the authors determined the perceived waiting time as a subfactor of psychological reactions of airline passengers. However, in our opinion, the authors did not take into consideration several factors that affect the image of an airport and the perception of passengers of this air transport enterprise.

That is why it is necessary to take into consideration additional significant factors: appropriate counteraction measures for each type and level of a threat, including activities of personnel and a set of appropriate technical facilities of protection of the object, which reflects the system of service quality.

Thus, this gives grounds for the feasibility of conducting a scientific conceptual study on the construction of an integrated system of aviation safety management, where integration itself becomes a controlled system of quality management, measured at all stages.

3. The aim and objectives of the study

The aim of this research is to manage the aviation safety of an airport based on the application of quality management. This will make it possible to determine the factors influencing aviation safety on the management of services quality at airports, as well as on the activities of the SAS service at an airport.

To achieve the set goal, the following tasks were to be solved:

- to develop a system of goals of key indicators of the effectiveness of integration processes of the aviation safety system at an airport based on the use of quality management;
- to determine the features of the SAS operator in the process of uninterrupted functioning of a complex system of interaction of airport services;
- to construct a model of aviation safety of an air transport enterprise in the system of quality management, taking into consideration the economic mechanism and the level of a threat.

4. Materials and methods of research

To obtain an objective assessment of functioning and implementation of the integration processes of the system of aviation safety at an airport, a systemic approach should be used to ensure its competitiveness, since the SAS is a subsystem of the system of quality management.

The systemic approach to the study of the aviation safety system is aimed at identifying functional features, properties, mechanisms of interaction between subsystems and elements, taking into consideration the influence of the external environment of these systems. That is why it is important to determine the place of aviation safety in the system of service quality of airport services (Fig. 1).

A high level of quality of service of all consumer segments is a totality of techniques and methods of providing various types of services, which is implemented on a given technical base, taking into consideration the criteria for influencing the choice of airport activities by consumers (Table 1). This contributes to the possibility of achieving the required level of airport competitiveness.

In the course of the study, we used the methods of analysis and synthesis to determine the key conceptual provisions of research works on the organization of aviation safety at airports.

The methods of systemic analysis were used in the study of the role of the SAS operator in the process of uninterrupted functioning of a complex system of interaction of airport services.

In the development of a system of key indicators of the effectiveness of integration processes for the implementation of the system of aviation safety of an airport based on the use of quality management, the methods for assessing economic effectiveness and optimizing management decisions were used.

The methods of statistical and factor analysis became the basis for the assessment of analytical materials of three airports to determine the cost of ensuring an adequate level of aviation safety as an optimal strategy based on the functional evaluation.

5. Results of development of conceptual provisions of effective management of issues of aviation safety at airports

5.1. Development of a system of key indicators of the effectiveness of integration processes of implementation of the system of aviation safety at an airport

The most difficult problem for airports of great loading with a large number of airlines, as well as for the states where airports are located, is the issue of ensuring effective protection against terrorism. The action of terrorists, its unpredictability is an unmanaged parameter of the system that shows the weaknesses of an airport and makes it possible to identify weaknesses in the inspection of passengers, baggage, cargo, and mail, etc.

Under modern conditions, the competitiveness of the offered airport services is stimulated by an increase in the needs and requirements of consumers, an increase in the level of critical assessment of aviation safety, which motivates to improve the quality of the offered services [12].

Awareness that an airport is in a competitive environment invariably leads to an understanding that quality is one of the basic elements in the management system, and its measurement is a key element in improving the effectiveness of its functioning.

The system of quality management (SQM) can be defined as: "A totality of coordinated measures of management and control over the organization in order to continuously improve the effectiveness of its activities". These measures interact and affect their being in the system, so separating and studying each element in detail will not necessarily lead to an understanding of the system in general. The main goal of the SQM is to identify the processes that will lead to the production of high-quality products and services, rather than to identify defective goods or services after their production.

Any organization benefits from the creation of an effective quality management system. Article [13] contains the system "The process of service quality management at airports", which does not take into consideration the dynamic development of technological processes of interaction of airport services in emergencies in accordance with the standards of air transport safety and necessary certification. Thus, Fig. 1 presents an improved quality management system, which reflects the integration of the system of aviation safety and ensures the relationship between the airport services, which is important in eliminating the threat of the emergence of the AUI.

Quality Management Systems ISO 9001:2000 and requirements for aviation safety ISAGO systematize generalized requirements. At the same time, there are no norms regulating the quality of services in terms of customer approach, as well as the system of quality management of airport infrastructure services.

In the current situation, the business entities of the airport services market faced the problem of the lack of unified approaches, criteria and methods for assessing the level of quality of airport services. This prompted the need to develop independent mechanisms for regulating the service activity.

The cornerstone of the organization of quality is the concept of a customer and a supplier working together for their mutual benefit. For this to become effective, the customer-supplier interfaces must be distributed to the organization and beyond, except for direct customers and suppliers.

Special maps based on the timing method, like questionnaires, were developed for quality managers in paper [14]. Respondents are asked to specify quantitative results for serviced passengers per unit of time, involved personnel, the number of used equipment, the queue length, service time, etc.

The merits of this procedure include quite careful processing of the criteria for assessment of the level of quality of airport services, a convenient form of a questionnaire for respondents.

The shortcomings of the procedure include the lack of assessment of the quality of airport services by airlines – direct consumers of services.

Assessment of quality of service by managers also seems quite ineffective, despite the developed objective evaluation criteria – an independent expert should evaluate the devised indicators in order to increase the objectivity of results.

A high level of service quality for all consumer segments means meeting their expectations and, at the same time, creating competitive advantages that are the key to long-term effective functioning and development.

The indicators of quality of provided services may vary with the interdependence of many factors, taking into consideration random ones, including consumer preferences, seasonal demand, region features, etc.

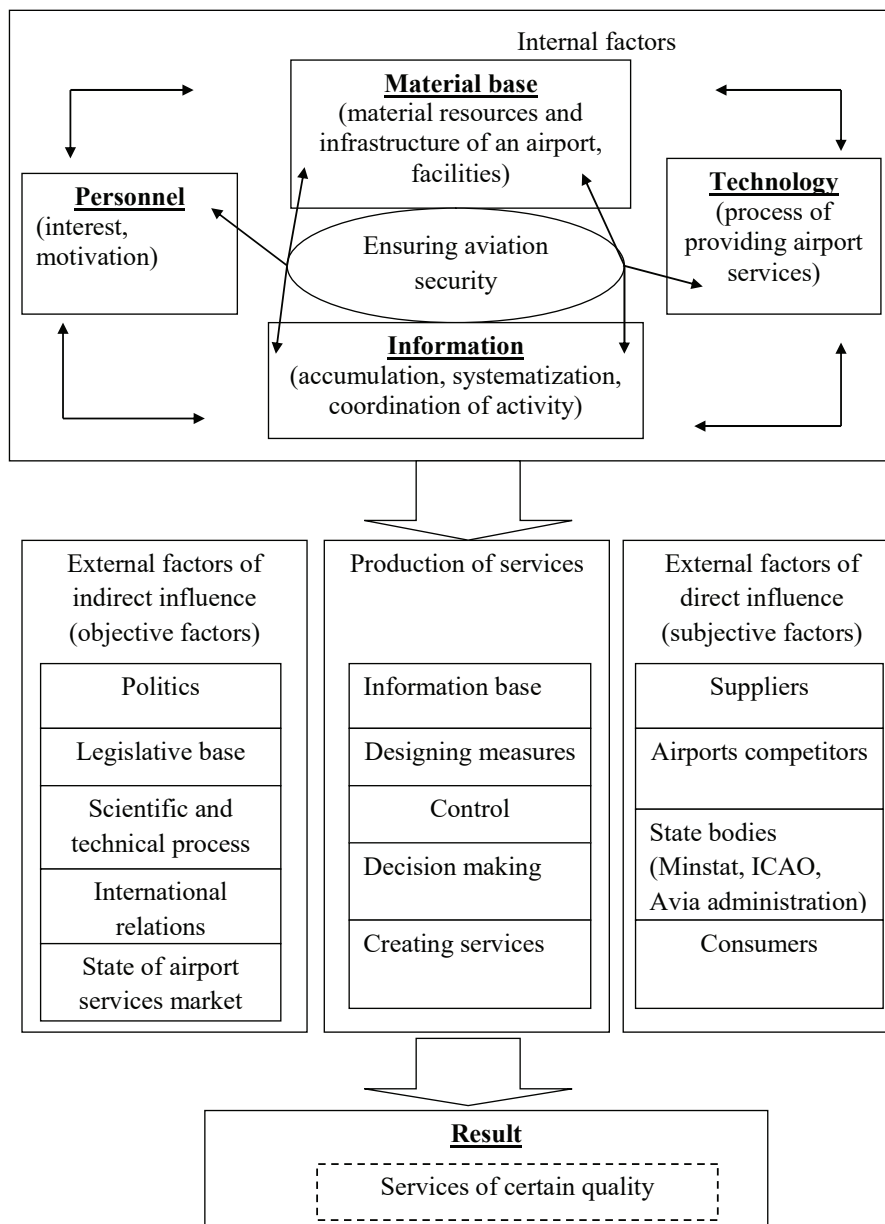


Fig. 1. Process of quality management of airport services, taking into consider ensuring aviation safety

That is why the criteria problem in deciding on determining parameters and establishing customer preferences will be the systematization of unsystematized criteria.

According to literary sources, the main criteria influencing the choice of an airport are indicated in Table 1 [15].

As a rule, in the practice of most marketing research conducted on air transport, 3 groups of parameters are separated according to their significance:

- the most significant;
- of medium significance;
- the least significant.

The level of quality of airport products is formed by impressions obtained from three main parameters of an airport:

- level I – from airport premises (airport square, parking place for cars, air terminal, its interior);
- level II – from performed maintenance processes;
- level III – from the activities of service personnel.

In the procedure of grouping categories, the specific feature of the technology for assessing the competitiveness

indicators (CA) of an airport is the existence of requirements from different categories of consumers of airport services, such as airlines, passengers, airport operators. Those, the share of which is at least 10 percent of the total value, belong to the group of the most significant parameters of choice.

Since the SAS belongs to level II of quality of airport products, it becomes necessary to determine its role and place in the airport competitiveness system. Fig. 2. shows the technology of assessment of aviation and non-aviation services according to the group indicator of the quality of the system of airport product of level II.

It was proposed to improve the indicators of quality of the airport product system by taking into consideration the AS factors, which are reflected in level II of group quality indicators.

According to the authors, the group quality indicator of the airport product system of level II contains other indicators that were not taken into consideration, namely, the impact of AS on:

- regularity and punctuality;
- quality of ground service of the aircraft;
- quality of service for consumers of airport products (clients).

Table 1

The main criteria for influencing the choice of airport activities by consumers

Consumers of airport services	Criteria of influence on the choice of airport services by consumers
For aviation companies	The potential of the target market; availability of slots at an acceptable time; the degree of presence of competitors; ensuring transfer connecting flights; connection with the route network; the amount of rates and fees; aviation flight safety; degree of modernization of airport infrastructure facilities
For passengers	Cost of transportation; the convenience of schedule; the number of possible routes; aviation safety of airport and airline activities; quality of aviation and non-aviation services; cost of delivery to the airport and parking; transport accessibility of the region (city boundary); courtesy of the staff when servicing
For cargo owners (senders and consignees)	Waiting time for receiving/giving cargo; schedule of terminal operation; preservation, terminal fees; aviation safety and access to the territory; procedures for receiving/giving; terminal equipment and living conditions; courtesy of the staff when servicing

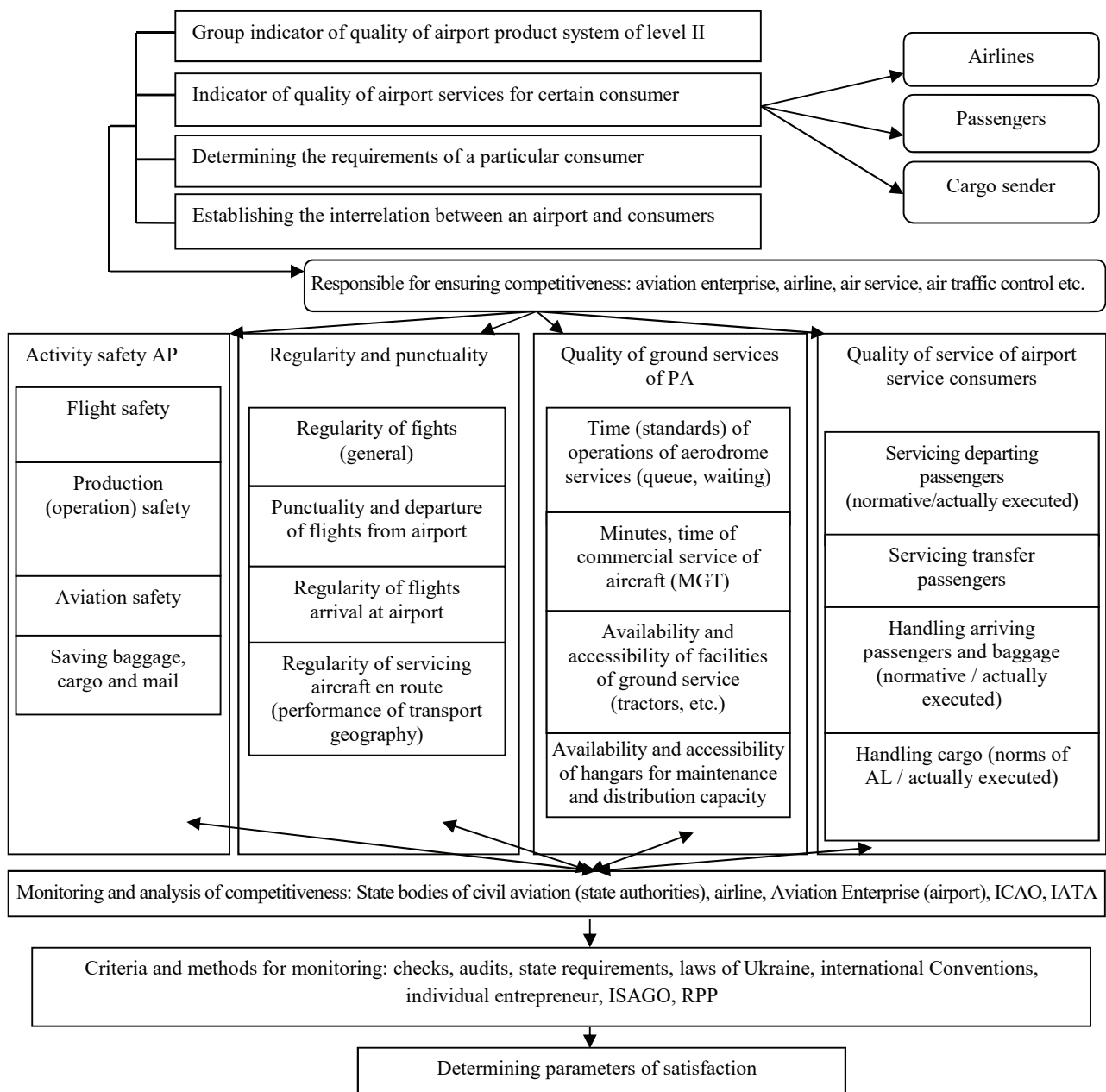


Fig. 2. The role and place of aviation safety system in the system of airport competitiveness

It is proposed to calculate the values of the given single indicators (Fig. 3) according to the following formulas:

$$K_{kc} = \frac{Y_1 + Y_2 + Y_3 + \dots + \frac{Y_{n-i}}{2}}{n-1}, \tag{1}$$

where n is the number of criteria; Y_{kci} is the calculated magnitudes of single criteria of quality of product system in the range from 1 to i , which are determined from formulas:

$$Y_{kci} = \frac{K_i}{K_{imax}}, \tag{2}$$

K_{imax} is the maximum value of the i -th indicator among those selected for analysis of the product of aviation enterprises; K_i is the value of the i -th indicator.

The proposed variant of a solution is used for those indicators, the increase in the values of which improves the competitiveness of an airport.

In the situation where the value of indicators, in which the quality of the system of providing airport services decreases, the following formula is suitable:

$$Y_{kci} = \frac{K_{imax} - K_i}{K_{imax}}. \tag{3}$$

Models of quality indicators (Fig. 3) are constructed as models of intersection, uniting or combination of effects in such a way that inequalities are true:

$$0 \leq K_i \leq 1. \tag{4}$$

Comprehensive indicators reflecting different aspects of the quality of the airport operation make it possible to construct an integrated indicator. There are several models proposed by the scientific community, taking into consideration different approaches to solving this problem.

Thus, taking into consideration the above, it is proposed to separate “the most significant” indicators: a comprehensive indicator of the quality of operation of personnel and

equipment (K_{qpe}) and comprehensive indicator of the quality of aviation safety (K_{qas}), which are quality indicators of AS and form a competitive position of an airport in the market. Other indicators are proposed to be considered as auxiliary with weight coefficients, reflecting complex models of a combination of effects (properties), where a group of “the most significant” indicators is used as the main comprehensive indicators.

This selection of indicators to the category “the most significant” is not accidental. Thus, the indicator of the quality of operation of personnel and equipment (K_{qpe}) is basic, which reflects the organizational and functional activities of the airport activity, and the indicator of the quality of aviation safety (K_{qas}) exists as a selection criterion in all three categories of consumers of airport products (Table 1).

$$K_{AP} = (K_{qpe} + K_{qas}) \cdot (a_1 K_{ta} + a_2 K_{ci} + a_3 K_{qca}), \tag{5}$$

$$a_1 + a_2 + a_3 = 1, \tag{6}$$

where K_{AP} is the integrated indicator of the quality of airport activity;

K_{ta} is the comprehensive indicator of transport availability and accessibility of an airport;

K_{ci} is the comprehensive indicator of comfort and information support at the airport;

K_{qpe} is the comprehensive indicator of the quality of operation of personnel and equipment;

K_{qas} is the comprehensive indicator of the quality of aviation safety;

K_{qca} is the comprehensive indicator of the quality of non-aviation services (commercial activity) of an airport.

For the purposes of expert evaluation, we considered the 9-point scale (Table 2) proposed by Thomas Saaty [16].

By the results of expert assessments of categories of quality indicators according to Table 1 as for the degree of their significance, the block diagram of the AP competitiveness is represented (Fig. 4). This block diagram was developed based on a survey at the Ukrainian international airport “Boryspil” and 2 Ukrainian airlines: “Ukraine International Airlines” and “SkyUp Airlines”. The sampling date is October 2020.

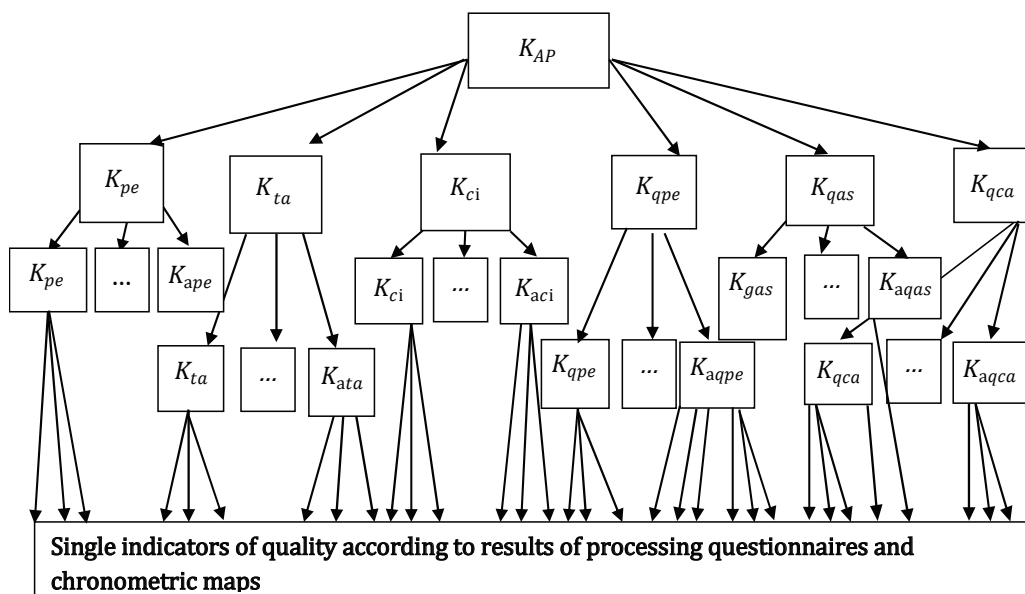


Fig. 3. Conceptual model of formation of the system of indicators for assessing the quality of airport operation [15]

Table 2

The scale of relative significance of objects of expert evaluation when choosing an airport product system

Intensity of relative significance, points	Definition	Explanation
1	Equal significance	Significance of objects (factors) K_i and K_j is the same
3	Moderate advantage of one over another	Experience and judgment give an easy advantage to one object (factor) over another
5	Essential or strong advantage	Existing data testify about the noticeable advantage of K_i over K_j
7	Very strong advantage	Advantage of object (factor) K_i over K_j is evident
9	Absolute advantage	Evident advantage of K_i over K_j is proved by all existing features
2, 4, 6, 8	Intermediate decisions	Used in compromise cases

Further application of this procedure is of a recommendation nature and enables the airport to apply the results for the comparative characteristics of its activities, which

will make it possible to increase the competitiveness in the target segment of airport services (for different time periods for corrective actions);

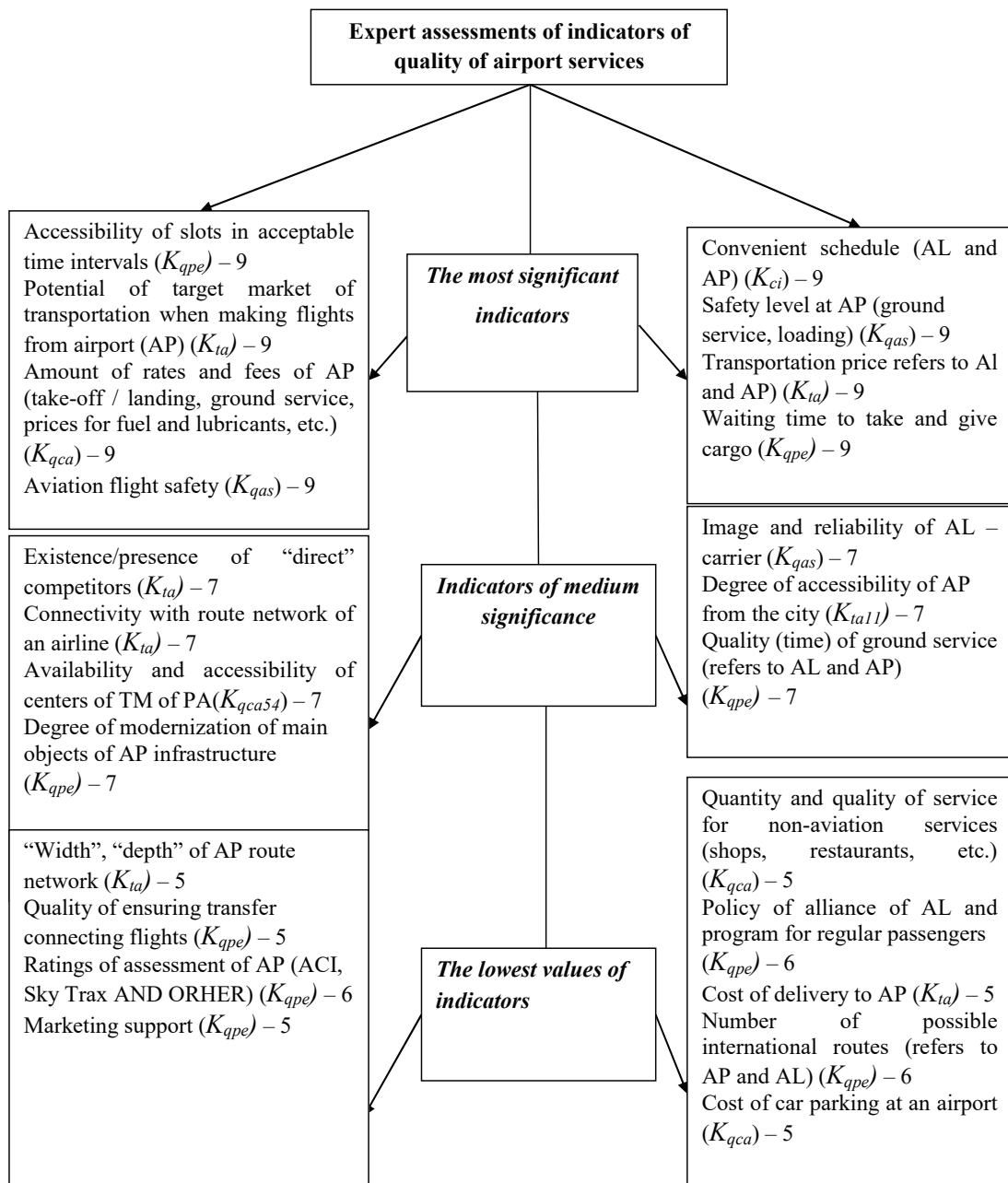


Fig. 4. Expert assessments of the competitiveness of airport services

The proposed system of indicators allows receiving objective information about the quality of airport services and the sustainability of production processes. Such information can be used to form and further implement the long-term goals of an airport in the area of aviation safety, quality of service and prices differentiated, depending on the requirements of consumers of airport services.

5. 2. Determining organizational and functional features of the operator of the aviation safety system in the process of airport services interaction

The satisfaction of consumers, which is implemented by providing high-quality airport services, is interdependent on the expectations and competitive advantages of the regional space.

The Australian Competition and Consumer Commission, as an independent body of Australia, in 2008 developed the “Guide to Monitoring the Quality of Airport Services”.

In this document, airport activities are classified as follows:

- activities related to passenger service;
- aviation activities;
- station facilities and facilities related to access to an airport;
- management efficiency.

Management over the proper implementation of aviation safety is the exclusive competence of an airport, it cannot be outsourced.

The need to organize aviation services as some universal quality management systems is outlined in the recommendations of ICAO. Special inspections are carried out in compliance with the aviation safety of an airport and a carrier.

It is checked if passengers have in their hand baggage the goods prohibited for air transportation (firearms, ammunition, explosives, flammable, toxic, poisonous, explosives, compressed and liquefied gases). The inspection is carried out to detect other substances and elements that can be accepted for air transportation only under special conditions.

This makes it possible to ensure the uniformity of interpretations, the main classifications of aviation activities. In addition, the airport system should automatically ensure reconstruction aviation services, when changing the requirements for the level of aviation safety that is, to meet the “quality standard”.

In reality, it is difficult to meet the reference value, given the continuous changes in the “quality standard”, and the SAS is not an exception. For example, the processes of activating terrorist elements in civil aviation (CA) lead to the need to revise the indicators of the SAS effectiveness. This, in turn, demands to increase the level of technical equipment of airport posts of SAS.

The Australian Commission is working with ICAO to ensure that global standards and recommended practices should be most appropriate for airports and helps airports meet these standards by developing guidelines and providing expert reviews.

The Airports Council International (ACI) cooperates with IATA. At the annual World Conference, the largest and most prestigious event in the field of safety, and within the framework of the Smart Safety project, the results of joint activities – initiatives aimed at the development of the next generation of passenger checkpoints – were presented.

Global airport safety technologies, industry, and markets are undergoing significant changes. While the American Transport Center market previously dominated, now dominance is moving to European, Middle Eastern, and Asia-Pacific airports. New mature sectors and technologies, such as automated border control kiosks, cargo checks, cybersecurity, airport perimeter safety systems, and advanced information and communication technologies create new niches and new business opportunities. Fig. 5 shows the level of aviation safety of airports in accordance with modern technologies for regions of the world as of 2020.

According to expert estimates, the global level of safety and video surveillance of airports according to analysts’ forecasts will increase by 7 % annually, from 2018 to 2024. According to the results of research of the consulting company Global Market Insights, the global market for ensuring the protection of air hubs by 2024 will be more than USD 15 billion.

The active implementation of safety measures is due to the high demand for modern high-tech systems, so it is easy to argue that standard measures of airport system protection are based on invasive procedures.

Airport safety systems are management and safety systems that are united into one and develop in the integration direction. Fig. 6 shows an improved airport safety system for passenger aviation safety levels, based on [17–20].

The purpose of this type of control is to prevent terrorist acts and taking hostages on board an aircraft, as well as to prevent the illegal export of prohibited items and substances.

Preliminary control of passengers and hand luggage is organized in a special control zone immediately before boarding an aircraft.

International standards ISO 180-9000 for any type of activity make it possible to use the theory of quality systems in the development and operation of the SAS systems.

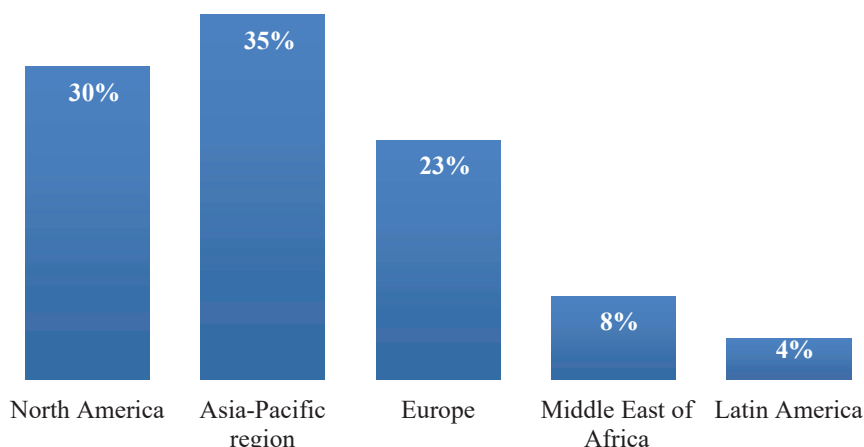


Fig. 5. Provision of modern technologies of aviation safety of airports for regions of the world as of 2020, [%]

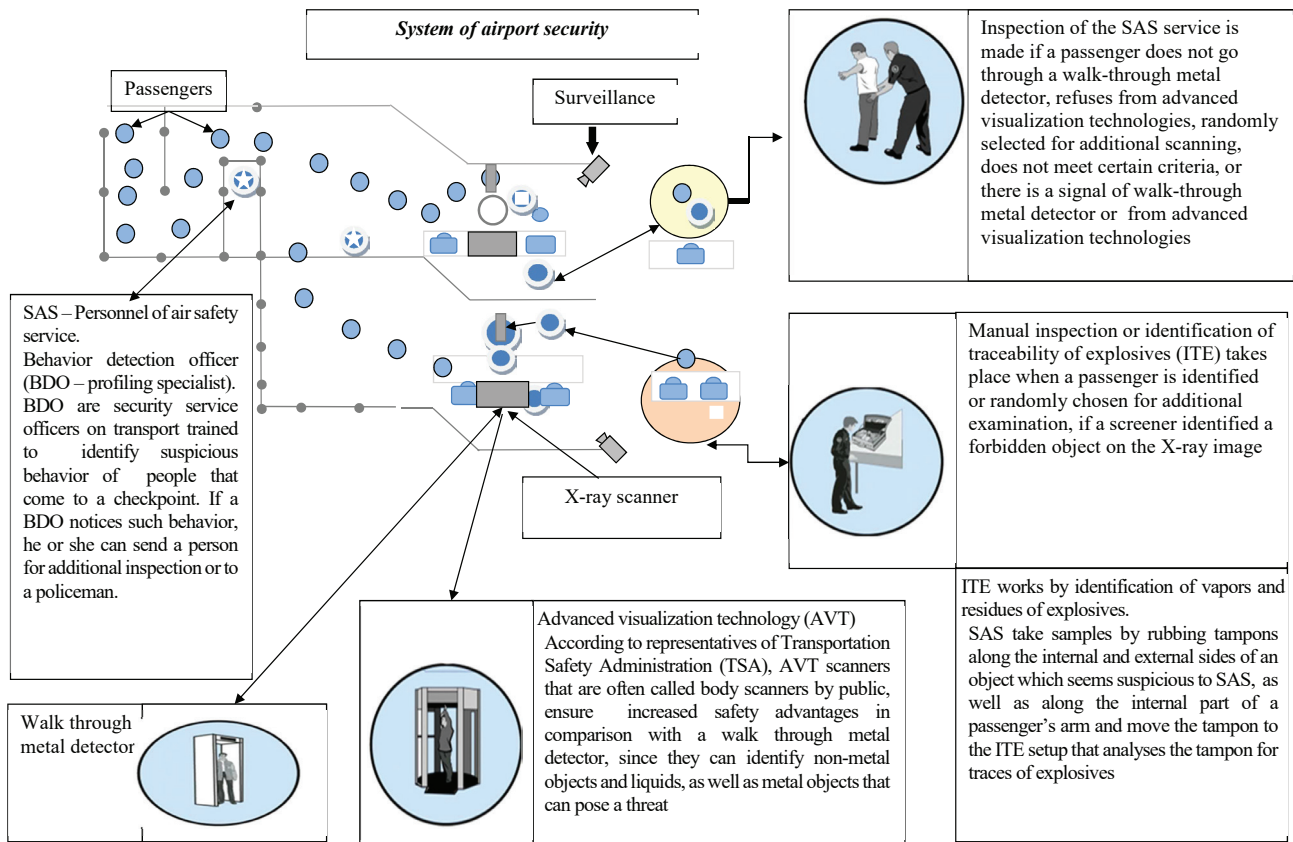


Fig. 6. Airport safety system for levels of passenger aviation safety

5.3. Construction of an integrated model of aviation safety of an airport taking into consideration the economic mechanism and threat level

The standardized level of ensuring the airport's AS does not reflect the essence of controlled processes of ensuring quality at all levels of the airline's activities. It is necessary to determine the strategic principles and perspective directions of the management component of the ISO quality management system and the requirements for aviation safety ISAGO as a methodological and instrumental management function, which is the basis of the airport activities. In addition, it will provide an opportunity to direct and stimulate the airport's activities for continuous, long-term work to meet consumer needs, taking into consideration the requirements for the provision of quality services. Accordingly, the economic mechanism acts as its controlled component, which makes it possible to interact with each other through the financial and economic levers of the system in general (Fig. 6 is compiled based on [21] and improved by the author's proposal).

Thus, the effectiveness of ensuring the AS of an aviation enterprise depends on the volume of costs to ensure the level of its threat. To this end, the authors identified the necessary resources to support them (material, informational, human) and analyzed the costs of aviation safety measures at airports. This analysis allowed concluding that in recent years the cost of aviation safety has increased on average by 49 % and amounts to 3–10 % in the structure of costs of air transport enterprises.

The calculation of fees for the AS showed that according to this method, they depend on the actual costs when allo-

ating the share of the company's profit for aviation safety, based on the predicted data on the volume of air transportation services.

The theory of quality management systems "quality standard" or "quality loop" determines the descriptive principles of system construction and makes it possible to construct initial functional schemes and in the future similar systems.

Airport safety technology is determined by the growth in the commercial air transport market and the need to handle a growing number of passengers without adverse influence on safety quality. In addition, new regulations, such as European ones when it comes to screening, should also influence trends associated with new technological solutions to replace or modernize existing measures. That is why it is extremely important that schedules should be correct and forecasting plans for different periods should be ready. This will guarantee that the airport management will take important steps to identify shortcomings in ensuring the interaction of airport services in emergencies and will improve the development of the airport complex in the future.

Organization, planning, and management directly affect the methods for management of an aviation enterprise. The effectiveness of functioning of the AS system and its provision depends on targeted, balanced management, where the main efforts of the airport authorities are aimed at implementing measures to reduce (or eliminate) threats.

ICAO policies and recommendations for charging fees to "users" do not contradict the Chicago Convention, so in practice, the costs of the airport AS are reimbursed at the expense of airport fees, which include aviation safety revenues.

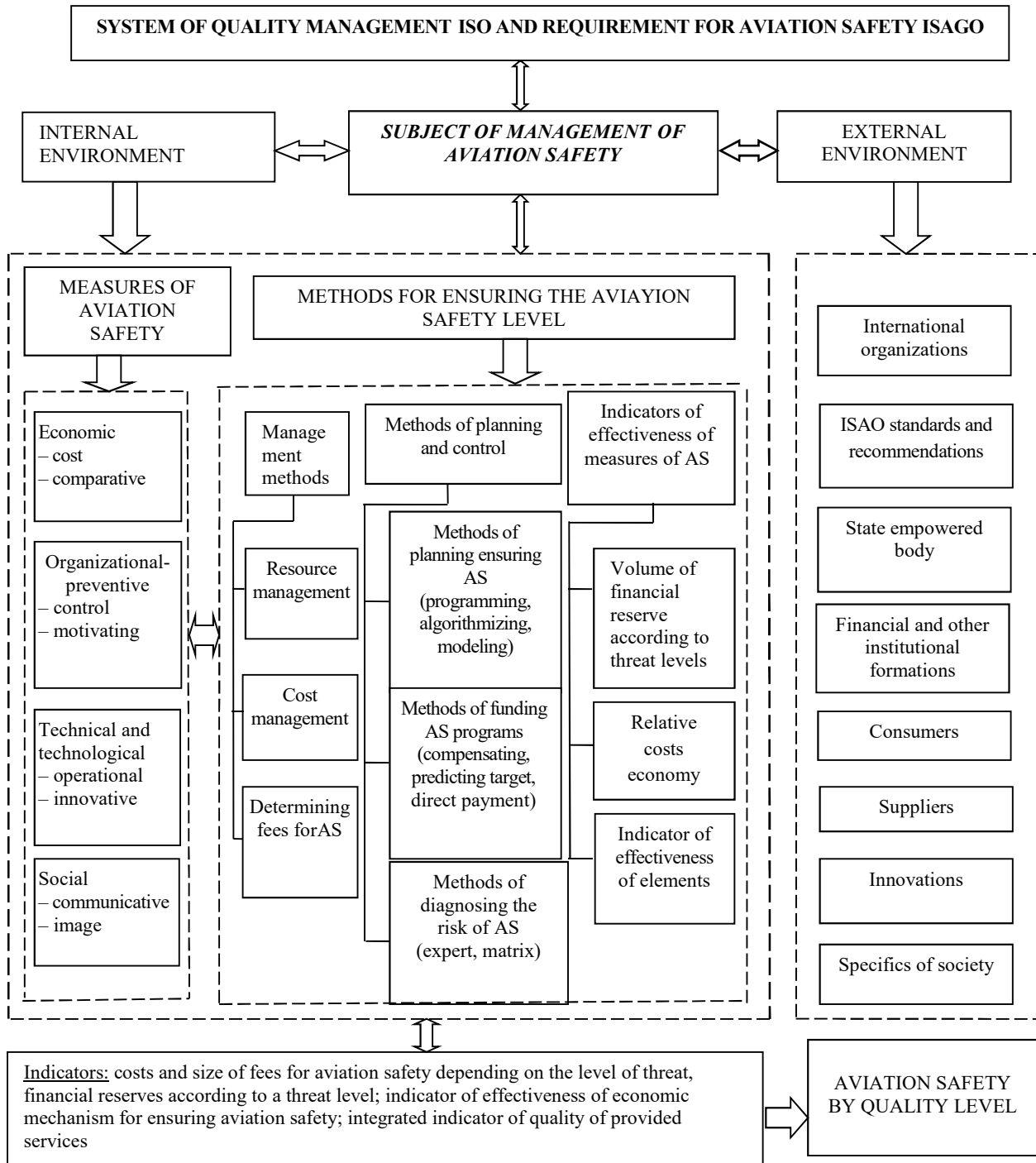


Fig. 7. Ensuring aviation safety of an air transport enterprise in the system of quality management, taking into consideration the economic mechanism

In his study, the author of [21] considers the method of controlling aviation safety resources as the first step in the formation of the AS means. According to the proposed method, the dependence of aviation safety measures (Y_i) of threat sub-levels (X_i) is presented as a matrix.

Using the matrix, we determine the amount of financial resources necessary to ensure an appropriate level of aviation safety in relation to the existing threat from the formula:

$$Y = \sum_{i=1}^n Y_j^i = \sum_{i=1}^n \sum_{j=1}^m \delta_j^i, \tag{7}$$

where i is the threat level;

N is the number of threat levels;

J is the AS measures;

M is the number of measures to ensure aviation safety;

δ_j^i is the Kronecker symbol.

The amount of total costs of the aviation company to ensure aviation safety, taking into consideration the level of threats, is determined from formula:

$$TC^i = \sum_{j=1}^m \delta_j^i C_{ab}^i(Y_j), \tag{8}$$

where TC^i is the total costs for activity and measures of the i -th treat level;

$C_{ab}^i(Y_j)$ is the costs of the j -th measure of aviation safety at the i -th threat level.

The share of costs of enterprises for aviation safety of air transport according to economic elements was determined empirically based on the source [20] and calculations were made taking into consideration the average performance indicators of Ukrainian airports for 2015–2019 (Table 3).

Table 3
The costs of air transport enterprises according to threat levels, (%)

Threat level	Costs				
	Direct material costs	Direct costs for salary	Other direct costs	General production costs	Total
“Green”	100.00	100.00	100.00	100.00	100.00
“Orange”	124.49	139.57	131.32	113.61	140.12
“Red”	161.21	191.39	161.11	148.69	187.31

Changes in the cost structure depending on the threat levels made it possible to determine the cost structure in the form of adjustment coefficients to the costs of aviation safety measures in accordance with the threat level: a – “green”; b – “orange” and c – red.

The minimum value of coefficient a is 1. This means that the total cost of aviation safety, which takes into consideration the cost of achieving the standard level of aviation safety, does not increase [20–22]. Adjustment coefficient b is 1.4 and c is 1.87, respectively.

Depending on the available information on the potential threat, the changes in aviation safety measures, and therefore the costs incurred, will be formed in the matrix taking into consideration the category of information of the cost assessment of differentiation of threats to the AUI (Table 4) [22].

Table 4
Matrix of cost estimation of differentiation of AUI threat

Threat possibility level	Characteristic of information about the possibility of AUI		
	No information about an existing threat	Availability of information about an existing threat	Availability of information about an existing threat
“Green” threat level-potential possibility	A	b_1	c_1
“Orange” threat level-probability	a_1	b	c_2
“Red” threat level-real	a_2	b_2	c

$a_1, a_2, b_1, b_2, c_1, c_2$ are the corresponding adjustment coefficients for basic and extended functional costs for aviation safety, taking into consideration the threat level:

$$\begin{aligned}
 a_1 &= b_1 = c = 1.0; \\
 a_2 &= c_1 = b = 1.4; \\
 b_2 &= c_2 = a = 1.87.
 \end{aligned}
 \tag{9}$$

The use of matrix coefficients makes it possible to substantiate the cost of aviation safety measures, taking into consideration the level of threat of possible AUI by multiplying the costs of ensuring a standardized (normative) level of aviation safety. Since each company has its own facilities of limited air transport to ensure aviation safety, it is possible to adjust coefficients $a, b,$ and $c,$ but not lower than the minimum required level [22, 23].

Thanks to embedded matrix assessment of threat differentiation, statistical and expert data on the probability of each of them, the scientific study assesses the probability of an AUI threat. This enables the authorities of an aviation enterprise to make a grounded decision when it comes to determining the cost of ensuring an adequate level of aviation safety in accordance with existing threats.

When forecasting the expected level of costs, we take into consideration the optimization-risk model of the AUI threat levels using the functional cost approach to determine the volume of costs at the i -th threat level and determine the likely costs for each threat level.

Probability of threats at each level:

$$p_1 = 0.88741; \quad p_2 = 0.06437; \quad p_3 = 0.04822,
 \tag{10}$$

where “green”, “orange” and “red” threats correspond to p_1, p_2, p_3 and are optimal frequencies of costs during a year (probabilistic approach).

Based on the probability of threats (10) at the total magnitude of costs for ensuring AS (8), we obtain the expected total annual aviation safety costs, which take into consideration acceptable costs according to the threat level (TC_{ab}) and are determined from the following formula:

$$TC_{ab} = \sum_{i=1}^n p_i TC_{ab}^i = \sum_{i=1}^n \sum_{j=1}^m p_i \delta_j^i C_{ab}^i(Y_j),
 \tag{11}$$

where p_i is the optimal frequency for i -th threat type for a year.

It is appropriate to determine the tariffs of airport charges for aviation safety (Z_{ab}) from formula (12) [21]. The authors propose to take into consideration a comprehensive indicator of aviation safety security quality for the i -th functional component of aviation safety, which subsequently amounts to an integrated indicator of the quality of provided services and is determined as follows:

$$Z_{ab} = \frac{TC_{as}}{Q} = \frac{\sum_{i=1}^n \sum_{j=1}^m p_i K_{asq} \delta_j^i C_{ab}^i(Y_j)}{Q},
 \tag{12}$$

where Q is the planned volume of services (works) in natural terms (tons, number of passengers, in terms of parking);

K_{gas} is the comprehensive indicator of the quality of aviation safety for the i -th functional component of aviation safety, with the combination of effects in the range from 1 to $i.$

Using (12), airport charges were set for some airports of Ukraine, taking into consideration the factor of threat to aviation safety.

The results of calculating the aviation safety fee at the required level are given in Table 5.

The tariff of airport fees for aviation safety security was applied for Boryspil International Airport in accordance with the order of the Ministry of Infrastructure No. 37 of January 26,

2018, and entered into force on February 1, 2018. Regulations on the application of discounts to airport charges.

Table 5

Tariffs of airport charges for aviation safety at the normative level for some airports of Ukraine (calculation was carried out in accordance with Order No. 398 of August 31, 2018)

Airports	Payment in USD, passenger
Boryspil	9.01
Kyiv (I. Sikorsky airport)	9.62
Kharkiv	6.57

Aviation safety fees in this case are reasonable, they are considered important for the aviation safety index as the costs of aviation safety measures adapted to the threat level.

The results of the implementation of the functional cost approach to determining the amount of the aircraft safety fee show that the cost of the fee can also be adjusted, depending on the level of threat to aviation safety. Adjustments are made using matrix assessment of threat differentiation (committing an act of unlawful interference), (Table 6).

As a result of calculations, the amount of payment for aviation safety using adjustment coefficients to counteract the threat of possible AUI will increase. This enables an aviation company to form a reserve in a timely manner to prevent or eliminate the consequences of the AUI by taking into consideration the aviation safety fee in the total cost of air transport services.

Table 6

Adjusted aviation safety fees, USD

Airports	Adjustment coefficients		
	<i>a</i>	<i>b</i>	<i>c</i>
Boryspil	9.01	12.61	16.85
Kyiv (I. Sikorsky airport)	9.62	13.47	17.99
Kharkiv	6.57	9.2	12.29

The management of the aviation company has the right to decide what additional set of measures it will apply at the highest standardized level of aviation safety to reduce possible losses.

Obtaining four types of efficiency – economic, organizational, technical, technological, and social, which in totality will constitute an integrated indicator, makes it possible to determine the effectiveness of the economic mechanism of aviation safety:

$$E = \sum_{i=1}^n E_i = \sum_{i=1}^n \sum_{j=1}^m E_i^j, \tag{13}$$

where E_i is the effectiveness of the i -th functional component of aviation safety;

M is the number of functional components;

n is the number of indicators of the effectiveness of aviation safety for its i -th functional component;

j is the kind of effectiveness for the i -th functional component;

E_i^j is the effectiveness for the type of the i -th functional component.

The effectiveness of a certain component is determined as the ratio of the amount of damage prevention and the cost

of aviation safety measures to the volume of costs incurred by the threat level.

The economic component of the mechanism of economic efficiency of ensuring aviation safety of air transport enterprises is calculated as the ratio of losses to the AUI costs for aviation safety measures in accordance with the threat level. The economic effectiveness of preventing one of the AUI is on average USD 27 thousand.

The financial reserve for ensuring aviation safety measures and the threat level is formed by exceeding the magnitude of the fee for aviation safety measures to prevent this threat. According to estimates for the level of the “red” threat of committing an act of unlawful interference, the amount of the financial reserve is zero, since the cost of measures to ensure the level of the “red” threat is equal to the size of the aviation safety fee. In the case of the “orange” threat level, the reserve size increases by 27 %, while in the case of the “green” threat – 44 % of the cost of measures to prevent the corresponding threat level.

6. Discussion of results of the proposed integrated system of airport aviation safety management based on the application of quality management

The realization that the competitive environment, in which an airport is, invariably leads to understanding that quality is one of the basic elements in the management system. A key element in improving the effectiveness of its functioning is its measurement.

Paper [13] contains the system “The process of management of airport services”, in contrast to which the process of interaction of airport services in case of emergencies of the system in accordance with aviation safety standards is taken into consideration, due to the integration of the AS with the quality management system (Fig. 1).

Information growth, a complication of inspection equipment, lack of time for processing and decision-making by SAS personnel, especially in emergencies, as well as in the case of an AUI, causes a need to solve the problem of implementing production activities under special conditions. These conditions are determined by increased risks to the health and life of people, as well as sufficient vulnerability of an airport.

It was proved that one of the factors that increase the competitiveness of an airport is its dependence on how effectively it manages available resources and realizes its own potential in the integration and technological process of providing the AS. To solve this problem, the study of organizational and technological features of an airport and the SAS activities in the aviation services market was carried out (Fig. 5) and an improved airport safety system at passenger aviation levels, based on [17–20], was proposed (Fig. 6).

Due to the assessment of the applied technologies of the timing method of the customer-supplier concept [14, 15], unsystematized criteria in the airport competitiveness system were systematized (Table 1) and the place and the role of the SAS was determined (Fig. 2). Based on this, the classification of the group indicator of the quality of the airport product system of level II was proposed (Fig. 3, formulas (1) to (4)). The “most significant” comprehensive indicators of the quality of airport operation of level II were separated, which makes it possible to construct an integral indicator (5), (6). Expert

evaluation [16] based on the results of the survey conducted based on the Ukrainian International Airport “Boryspil” and 2 Ukrainian airlines: Ukraine International Airlines and SkyUp Airlines provided expert assessments of the quality of airport services (Fig. 4). This made it possible to divide quality indicators into three groups: the most significant; of medium significance; the least significant. The use of this approach made it possible to obtain a solution to increase the competitiveness of an airport and an airline in the aviation services market.

It may be considered appropriate to determine the tariffs of airport charges for aviation safety (Z_{ab}), as proposed in paper [21], but in order to achieve the best results of strategic management, it is necessary to take into consideration a comprehensive indicator of the quality of aviation safety for the i -th functional component of the AS (Fig. 6, formula (12)), which makes it possible to form an integrated indicator of the quality of services provided. Thanks to the mathematical modeling (formula (7)–(13), Tables 3–5), an assessment of the cost approach to the aviation safety system in the continuous implementation of the quality management system was made. The results obtained in this case (Table 6) form the calculated adjusted magnitudes of aviation safety fee for 3 Ukrainian airports, which allows the timely formation of a reserve for prevention or elimination of the consequences of the AUI.

The specific feature of the main limitation is that the AUI is unpredictable. This makes it impossible to take into consideration the unpredictability of the AUI states. In addition, for different airports, the system of ensuring the AS taking into consideration the quality system will be different, since it is necessary to take into consideration the airport class, production indicators, and available resources when constructing the AUI risk matrix in the long-term prospect of airport development.

This study may be developed in the context of changes in the standardization of aviation safety and standards of a quality management system.

7. Conclusions

1. It was proved that the airport aviation safety system has a significant impact on the quality and competitiveness of the offered airport services. The improved quality management system, proposed in the research, reflecting the integration processes of the aviation safety system, ensures the relationship between the airport services. This makes it possible to act promptly in eliminating the threat of the emergence of the AUI. The use of group indicators of the quality of the airport product system, taking into consideration the AS factors, makes it possible to determine the degree of satisfaction of different categories of consumers of airport services.

2. The developed generalized system of aviation safety reflects the functional management and safety actions of all elements of the system. This makes it possible to automatically ensure restructuring aviation services in accordance with the “quality standard” within the airport system when changing the requirements to the level of aviation safety.

3. The approbation of the devised aviation safety model, which reflects the management of aviation safety resources, proves its expediency in determining the total costs of the aviation company to ensure aviation safety, taking into consideration the level of threats. The proposed model takes into account a comprehensive indicator of the quality of aviation safety for the i -th functional component of aviation safety, which further forms an integrated indicator of the quality of provided services. The application of the model makes it possible to form airport fees for airports considering the factor of threat to aviation safety.

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