

Development of the Mathematical Model of Integrated Management System for an Airline

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Abstract – At the present stage of airline development the most effective way to increase safety is to introduce a systematic approach to the management of the organization. The creation of a single integrated management system including the combination of resources will make it possible to maintain the necessary level of quality of aviation services with safety as a key indicator. The article offers a model of such an integrated management system for medium level airlines.

Keywords – Aircraft, airline, flight safety, management system, process approach, quality indicators, quality management system.

I. INTRODUCTION

The main goal of any airline is to remain competitive in the market of air transportation services. This contributes to the implementation of air transportation with the lowest possible material, energy and time spent on the specified route without compromising the health of the participants of air transportation, surrounding environment, safety of transported objects (both quantity and quality), as well as preventing damage or destruction of equipment including the aircraft, infrastructure and other property which might be affected by the transportation process. The organizational structure of management plays an important role within the system of quality assurance in air transportation. It must provide high efficiency, reliability and comprehensive control of the whole air transportation processes.

The development of an integrated management system gives the opportunity to combine resources for maintaining the required level of safety and ensure the competitiveness of the organization.

II. THE PROCESS APPROACH IN THE INTEGRATED QUALITY MANAGEMENT SYSTEM WITHIN AN AIRLINE

Any enterprise can be considered as a set of manufacturing processes (activity areas).

Each of these processes is impacted by the relevant management system, which is developed, certified, implemented and managed in accordance with international standards [1]–[3]. The management system of an airline includes organizational structure, responsibilities, policies and procedures [4], [5]. These elements are common to all individual management systems.

In aviation enterprises, all these management systems can be combined and organized into a single integrated management system. The quality management system in that case can be used as a basic system. The process approach is an important principle, which is the basis of the quality management system in the International Standards ISO 9000 family aimed to improve clients' satisfaction.

In order to operate effectively, organizations must identify and manage numerous interrelated processes. Often the output of one process directly forms the input of the next process. In organizations, application of system processes along with their identity and interaction as well as management processes can be considered as “process approach” [6], [7].

Each process in the functional model is represented as the input of resources and output of used resources.

For the purpose of our research, taking into account the above information, in the integrated quality management system we will proceed from the following:

- among all the processes within the airline we will outline the processes determining the quality of the final product of air transportation;
- the processes of the airline are different in nature: flight operations, maintenance, commercial, etc. and have different effects on the quality of final product.
- The process model of the airline can be represented as a set of three processes, which are listed below [8], [9].
- the process of investment in scientific and technological progress in the field of creation of modern aircraft and their acquisition by the airline, depreciation of fixed assets, equipment upgrades, etc.;
- the process of operation characterized by the dynamics of operating material consumption and their cost (combustive-lubricating materials, depreciation of aircraft and equipment, current repairs and maintenance, etc.);
- the process of obtaining final results. The final results of airline activities are characterized by dynamics in the changes of work volume (tonne-kilometres, number of passengers, etc.) and dynamics in the changes of the level of transport service quality (in particular social criteria: flight safety, service level, indicators of environmental impact etc.).

The interrelation of these processes results in the achievement of airline's objectives, which determine the airline's competitiveness. We will consider changes in the indicators of these processes in the final time interval as:

- D_1 : the dynamics of change in final useful results: airline quantitative indicators, for example, the number of tonne-kilometres (W_{tkm}); safety level (K_1); ecological (K_2); service (K_3) and other quality indicators. We will designate these indicators as, for example, $a_1, a_2, a_3, \dots, a_n$.
- D_2 : the dynamics of change in different material factors (material and technical) is reflected in the dynamics of change in investments in production.
- D_3 : the dynamics of change in factors that characterize operational conditions.

During the production of transportation services, D_1 , D_2 and D_3 may have one of the six different statuses (1):

$$\begin{array}{ll}
 1. D_1 > D_2 > D_3; & 4. D_1 > D_3 > D_2; \\
 2. D_2 > D_1 > D_3; & 5. D_3 > D_2 > D_1; \\
 3. D_2 > D_3 > D_1; & 6. D_3 > D_1 > D_2.
 \end{array} \tag{1}$$

The objective of the integrated management system is to identify the relationship between D_1 , D_2 and D_3 , which best meet the objectives of the airline and society [11].

We will consider their possible combinations [12], [13].

If $D_3 > D_2$, the dynamics of changes in operating costs exceeds the growth of investment in infrastructure, and it means that the investments are not caused by operating cost savings, or the operational activities of the airline do not promote their effective use.

Therefore, ratio $D_3 > D_2$ does not satisfy the public needs. It is better to take $D_2 > D_3$. However, at the same time, lowering of these expenses provides benefit only if it causes the growth of final useful results ($W_{tkm}, K_1, K_2, K_3, \dots, K_m, a_1, a_2, a_3, \dots, a_n$).

The growth dynamics of final useful results should exceed the changes in D_2 and D_3 indicators. This requirement follows from the need to improve the efficiency of production and the quality of transport products.

Otherwise, at each moment in time during the operation of the aircraft, the company will be getting less transport products per unit of the above costs with a lower level of safety, frequency and service culture, which is in contrast with the public needs.

Thus, the ratio that best meets the public needs has the following form:

$$D_1 > D_2 > D_3. \quad (2)$$

This means that the dynamics of the development of material factors should be ahead of the development of operational ones, since qualitative and quantitative changes in the airline's material resources of should lead to a relative reduction in the number of operational factors affecting the transport process.

This occurs due to the increase in the reliability of technical systems, reduction of non-productive manual labour, downtime, waste of resource, etc. However, the reduction in operational factors should help to maximize the growth of final useful results; in such a case the reduction is not contrary to the purpose of airline operation.

Any deviations of safety and operational factors must be compensated by the airline.

Material factors are increasing due to quantitative and qualitative changes and new investments, while operational factors are increasing due to additional activities and measures.

Observance of ratio $D_1 > D_2 > D_3$ during airline operation means the proportional increase (decrease) of indicators. This ratio is ensured by proper structural and investment policy.

III.A MODEL OF INTEGRATED MANAGEMENT SYSTEM WITHIN THE AIRLINE

From the science of quality it is known that the indicators of the quality of products and services can be individual (characterize only one property), complex (characterize one or more properties), generalized (characterize a combination of properties), integral (also include the costs of the received quality indicators). In general, the mathematical model can be expressed as:

$$W_{\text{tkm ef}} = f(W_{\text{tkm}}, K_1, K_2, K_3, \dots, K_m, a_1, a_2, a_3, \dots, a_n), \quad (3)$$

where

$W_{\text{tkm ef}}$ effective volume of airline transport with regard to its quality over time;

$K_1, K_2, K_3, \dots, K_m$ complex indicators of the quality of services provided by the airline according to the safety level K_1 , the speed of delivery of passengers and cargo K_2 , regularity K_3 , services provided to passengers and clients K_4 , etc. and individual quality indicators a_1, a_2, a_3 (technical, economic) that characterize the three processes in airline functioning.

All these indicators are dimensionless. In the absence of the integrated management system, they are supported by individual management systems:

$$a_{1i} = f(D_1); \quad a_{2i} = f(D_2); \quad a_{3i} = f(D_3). \quad (4)$$

Complex quality indicators K_i can be integrated into generalized indicator K_t by using one of the coagulation methods [14]:

$$K_t = f(K_1, K_2, K_3, \dots, K_m). \quad (5)$$

Generalized quality indicator K_t is a quantitative quality indicator of the services provided by the airline to its customers.

Multiplying K_t with W_{tkm} (transport products provided to customers during a specific period of time), we obtain the amount of products with account quality, i.e. effective volume $W_{\text{tkm ef}}$:

$$W_{\text{tkm ef}} = W_{\text{tkm}} K_t. \quad (6)$$

It is also important for the airline to know at what price effective volume $W_{\text{tkm ef}}$ is received. The answer to this question can be provided by integral quality indicator K_{int} , which is expressed by the ratio of effective volume to total costs ΣS required for these purposes:

$$K_{\text{int}} = \frac{W_{\text{tkm ef}}}{\sum C}. \quad (7)$$

The mathematical model [4] is represented by the ratio of parameters K_i with aviation safety is a priority.

Therefore, considering index K_i in dynamics, it is important to take into account the properties and factors by way of which the change was achieved.

In principle, a situation is possible when activities K_i of the airline may increase due to the high rate of cost reduction with constant or decreasing effective volume. In another case, the growth of effective volumes can be caused by a higher growth rate of its quantitative side rather than the growth rate of the qualitative side.

Moreover, there are options when the same value of K_i can be achieved by various combinations of indicators included in the calculation model, depending on the method of coagulation used. Therefore, the task of the integrated management system is to determine the ratio of indicator change rates (3) which would best promote the airline's competitiveness in the market of air transport services.

IV. METHODOLOGY OF CREATING GENERALIZED AND INDIVIDUAL INDICATORS CHARACTERIZING THE QUALITY OF AIRLINE OPERATION WITH ACCOUNT OF THE LEVEL OF FLIGHT SAFETY

The quality of the airline from the point of view of the level of flight safety is characterized by two indicators: D_2 (the dynamics of changes in the indicators of investments in the main production assets of the airline) and D_3 (the dynamics of changes in factors characterizing operational conditions) [10].

D_2 consists of two individual indicators:

- changes in the value of investments in the fleet reflects the dynamics of the diversity of the material factors caused by the quantitative and qualitative changes in the fleet;
- changes in the value of investments in the airline's infrastructure.

D_3 includes eight indicators:

- aviation petrol, oils and lubricants;
- depreciation of aircraft fleet;
- current repairs of aircraft fleet;
- crew salary;
- aviation engineers' salary;
- salary of other ground staff;
- airport costs;
- production costs of engineering services.

The ranking of the sequence of indicator changes can be carried out with the help of normative standards determined according to the relevant procedure, which is not the subject of this article.

Then it is required to evaluate the differences between the actual and normative values of each indicator. This is ensured by using correlation theory.

The following expression can be used to calculate the correlation:

$$K_P^B = 1 - \frac{\sigma \sum_{i=1}^n y^2}{n(n^2-1)}. \quad (8)$$

Sequence of K_P^B is as follows:

1. a difference between its place in the normative and actual rank number is calculated for each indicator:

$$y = 1 - x_i; \quad i = 1, 2, \dots, n, \quad (9)$$

where

y – difference between the normative and actual indicator of the rank;

- I normative ranked indicator;
 x_i actual ranked indicator;
 n number of indicators included in the analysis.
2. a squared difference (deviation) between the rank and actual place, that is y^2 , is calculated for each indicator;
 3. a sum of squared differences (deviations) for all indicators, that is $\sum y^2$, is calculated.
- To calculate the indicator movement in the analysed period t , the following formula is used:

$$t_i = \frac{g_i - q_i}{q_i}, \quad (10)$$

where

- g_i absolute value of the indicator in the analysed period;
 q_i minimum absolute value of the indicator among the values preceding the analysed period.

It is important to take into account the movement of each indicator in relation to the most important indicator of the analysed system, which should be flight safety (this definition is not the subject of study in this article as well).

The final form of comparison of various indicator changes in time is a comparison of their movement with the movement of a separate indicator, with the measure of movement of the first indicator.

And this is nothing else than the index of movement of this indicator. In addition, it is recommended to take the maximum value of the limiting indicator in the analysed period g_{\max} rather than the actual limiting indicator. The formula for calculating index a_i is:

$$a_i = \frac{\left(\frac{g_i - q_i}{q_i}\right)}{\left(\frac{g_{\max} - q_i}{q_i}\right)}. \quad (11)$$

With the help of a_i it is possible to detect the movement of all the analysed indicators relatively to the movement of “flight safety” indicator.

The next step is placing the ranks in accordance with the value of indices.

Based on the essence of the process being investigated, the movement index for flight safety should grow faster than all other indexes.

After taking the aircraft out of service the indexes become negative (the requirement “to grow first” would mean “to decrease the last”).

In any case, the movement index for flight safety should be ahead of other movement indices in terms of absolute values, i.e.:

$$a_i > |a_i| \quad (12)$$

If a_1 takes a negative value, the safety indicator should take the last place in the actual rank order.

If unsuccessful events do not happen on the analysed type of aircraft, it is necessary to develop a new methodology for determining the level of safety that takes into account the variations which are smaller than activity variations.

The calculation can be conveniently carried out with the help of Table I.

TABLE I
CALCULATION

Factor groups	Factor sub-groups	Indicators	Actual ranked index, x_i	Normative ranked index, i	Difference (deviation) between the normative and actual index of the rank, y	The squared difference (deviation) between the rank and the actual place, y^2
D_1	1.1	Flight safety	Note 1	1	Note 1	Note 1
	1.2	The tonne-kilometre performance	Note 1	2	Note 1	Note 1
D_2	2.1	The overall investment in airports	Note 1	3	Note 1	Note 1
	2.2	The overall investment in aircraft fleet	1 Note 2	4	4-1 = 3 Note 2	9 Note 2
D_3	3.1	Aviation petrol, oil and lubricants	Note 1	5	Note 1	Note 1
	3.2	Depreciation of aircraft fleet	Note 1	6	Note 1	Note 1
	3.3	Current repairs of aircraft fleet	Note 1	7	Note 1	Note 1
	3.4	Crew salary	Note 1	8	Note 1	Note 1
	3.5	Aviation engineers' salary	Note 1	9	Note 1	Note 1
	3.6	Salary of other ground staff	Note 1	10	Note 1	Note 1
	3.7	Airport taxes and expenses	Note 1	11	Note 1	Note 1
	3.8	Production costs of Technical Centre	Note 1	12	Note 1	Note 1
The number of indicators included in the analysis, n	12					

Note 1: to be researched (is not the subject of study in this article).

Note 2: taken as example to show calculation.

V. CONCLUSION

The results of the research conducted by the authors on air transport organizations make it possible to draw the following conclusions:

- the assessment of the level of transport product quality through factors K_i is quite sensitive, informative and reliable. It allows to capture the changes in industrial and economic conditions and in factors related to potential reduction of aviation safety;
- during the process of research, the following important theoretical relationship was revealed: the higher the tendency to approach the actual ratio D_1 , D_2 , D_3 to the normative, the greater the tendency to increase the level of safety;
- the research into the causes of non-compliance of actual ratio D_1 , D_2 and D_3 to the normative one allows:
 - a. to determine the groups of industrial and economic factors reducing flight safety;
 - b. to identify trends in the industrial and economic conditions of transportation, which are contrary to the process of improving flight safety;
 - c. to determine the direction in the development of industrial and economic

environment of the airline.

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