DE GRUYTER OPEN
1862
RIGA TECHNICAL UNIVERSITY
Transport and Aerospace Engineering
ISSN 2255-9876 (online)
ISSN 2255-968X (print)
2018, vol. 6, pp. 15–21
doi: 10.2478/tae-2018-0002
https://www.degruyter.com/view/j/tae

Airline Quality Assessment Methodology Taking Into Account the Flight Safety Level Based on Factor Analysis

Ruta Bogdane[1], Aleksandrs Bitiņš[2], Vladimirs Šestakovs[3], Yasaratne Bandara Dissanayake [4]

[1–3] *Institute of Aeronautics, Faculty of Mechanical Engineering, Transport and Aeronautics, Riga Technical University, Riga, Latvia*
[4] *2YD Aeronautical Engineering Services LTD, Essex, England*

***Abstract* – In this article, the authors offer a methodology for determining the quality of airline performance by taking into account the level of flight safety on the basis of factor analysis and the results of methodology approbation in the conditions of a functioning airline. The assessment of the level of airline performance quality taking into account the level of flight safety within a certain time span is rather sensitive, informative and reliable. They allow us to detect those changes in industrial and economic conditions and factors that are related to a certain degree of potential deterioration of flight safety. This creates conditions for revealing the tendencies towards the deterioration of flight safety at the stage of their origin, when they have not yet caused deep, irreversible changes in the flight safety of an airline.**

***Keywords* – Aircraft, factor analysis, faulty condition, flight delay, management efficiency, management system, process approach.**

I. Introduction

Process approach is the important principle base of quality management determination in aviation services.

Process approach application to an airline quality management means that these services can be represented as a system of flows and factors that are in constant movement and interaction, that is a set of processes. It means that approach of the systems is needed in the aspect of providing flights safety, as one of principles of standards ISO-9000 [1]–[3]. Such approach allows to take together and analyse all possible risk factors in an airline and could recommend some actions which necessary to increase strength of safety [4]–[7]. As shown in [8], by using complex approach, the airline`s activity can be presented as a group of 3 processes, where each process has its own change dynamics of influence factors, which determines those processes in the final time step:

- D_1 – the dynamics of final effective result changes;
- D_2 – the dynamics of changes in the factors characterizing the airline’s infrastructure and aircraft fleet;
- D_3 – the dynamics of aircraft service factor changes.

The following relation presents the normal condition for airline development:

$$D_1 > D_2 > D_3. \quad (1)$$

Adherence to the above relation ensures the natural proportional growth of factors which have positive effect on the final result. It means airline growth and efficiency increase for making it more competitive [9].

II. Ranking of Indexes, Characterizing the Mode of Airline Operations on Period of Time

During airline service, interaction of different factors takes place at any moment of time: financial, personal, economic factors, as well as natural and climatic conditions, etc. In the considered time period, the final results of airline activity correspond to a certain combination of factors: volume of transportations and their quality with flight safety as a main priority. To determine the connection between the flight safety level and economic-industrial factors, the factor analysis will be used. The factor analysis is based on factor index ranking. If all the factors related to one of the airline`s functional aspects are sorted in the order of decrease of their relative increase within a certain period of time (year, month, etc.), we will get a row of indexes describing the mode of airline service in this period of time. These indexes allow to identify some unwanted relations in the factor change dynamics, e.g. a higher growth of aircraft incidents compared to the growth in the volume of air transportations, a higher growth of aircraft maintenance costs compared to the growth of aircraft fleet technical condition airworthiness, etc. The analysis of index group position in the row is very informative.

In addition, a simple comparative analysis of actual and theoretically optimal rows by differences and inversions of ranks allows to evaluate the degree of accordance of the actual and desired row and to reveal chains of connected indicators. In accordance to the accepted model, we have a set of factors and indexes for airline functioning that has the following semantic value [8], [10]:

- Dynamics of changes in safety performance indicators.
- Dynamics of changes in airline operation indicators.
- Dynamics of changes in investments for a certain period.

Indicator group D_3. The dynamics of the groups of factors characterizing changes in the operational conditions of aircraft fleet can be conveniently considered in the form of the dynamics of changes in the values of the corresponding items of expenses in monetary terms. It should be taken into account that each airline will have its own characteristics. This is because the airline usually performs work related to not only transport activities – it may also perform other activities. In this case, it is necessary to correctly allocate costs by types of transport operations, and then to distribute them by types of transportation (passengers or cargo) and types of aircraft. It is expedient to carry out the distribution of expenses by types of transportation and aircraft types with the help of a methodology based on the allocation of indirect costs by types of transportation multiplied by the distribution coefficients that simulate the actual processes of indirect cost formation and take into account the impact of changes in commercial load (by transport types) and conditions of aircraft operation. This principle of distribution, as shown by practical calculations, significantly increases the accuracy of determining the cost price of passenger and cargo freight, and ultimately allows you to obtain a more real cost price of the products listed [11], [12]. For the purposes of our research, we use the following items of expenses (this choice is not fundamental – there may be another set of indicators for assessing the dynamics of a group of factors characterizing changes in operating conditions):

3.1. Flight crew salary;
3.2. Lubricating materials, oil and greases;
3.3. Aircraft depreciation (amortization);
3.4. Aircraft maintenance and repair;
3.5. Production expenses of the technical centre;
3.6. Salary of technical centre employees;
3.7. Salary of support staff;
3.8. Unforeseen expenses.

Consequently:

3.1 The changes in the size of the cost group “Flight crew salary” reflects changes in the activity of the crew. The model by which the crew salary expenses are determined takes into account the type of aircraft, the area of operation, the complexity of the route, the time of flight operations (day and night) etc.;

3.2 The changes of costs under the item “Lubricating materials, oil and greases” reflects the consumption of fuel and other lubricating materials in different climatic conditions, at different modes of aircraft operation, with account of costs in different countries, etc.;

3.3. The change of expenses under the item “Aircraft depreciation (amortization)” reflects changes in the group of factors characterizing the process of aircraft depreciation;

3.4, 3.5, 3.7, 3.8 Change of costs under articles and groups: “Maintenance of airline fleet”, “Technical control centre expenses” and “Salary of technical staff”, characterizes content of maintenance and repair of aircraft. In general articles reflect the changes in “Continue Airworthiness Management and Maintenance” in the airline;

3.6. The changes in the size of the cost group “Salary of support staff” and the item “Unforeseen expenses” reflect changes in factors conditioned by the activities of other staff, as well as by the conditions of the maintenance and repair of buildings, constructions, equipment, etc.

In the mathematical sense, the dynamics of change of the specified indicators represents a time derivative of each of them – d_{ij}. Here, i is the index of process, j is the index of the indicator of the process under consideration. In general, the functioning of the airline as a large complex system can be presented as interaction of processes D_2 and D_3. At the same time, it helps to achieve one of the airline’s goals – to obtain final useful results, which are also reflected in the dynamics of D_1 (d_{11}, d_{12}): changes in the time of flight safety indicators – (d_{11}) and the volume of transport products (d_{12}). As it is stated above, the optimum condition of the airline and its development are characterized by the ratio: $D_1 > D_2 > D_3$. It is interpreted in the following way. Changes of final results of airline: d_{11} and d_{12}, shall overtake growth dynamics of operating expenses.

III. Development of a Standard (Reference) Indicator Rating

The first group of indicators, D_1, which reflect the diversity of the final useful results, includes two indicators: the flight safety factor K_t – (dimensionless) and the volume of air traffic flow (passenger or cargo) W. The safety indicator of transportation has an absolute priority over the indicator of the volume of production. In other words, the dynamics (derivative) of the growth of air safety level indicator d_{11} should outpace the dynamics of growth in the volume of traffic d_{12}.

$$d_{11} > d_{12}. \tag{2}$$

This means that in the first place of the rating there is d_{11}, in the second – d_{12}. The second group of indicators D_2, which determine the variety of material factors of the company's infrastructure, also includes two indicators: general investments in aircraft, F_{gk} (d_{22}), and infrastructure, F (d_{21}). Experience shows that in civil aviation the present level of development of the material and technical basis at enterprises generally lags behind the level of aircraft development. Taking into account this fact, we will establish a normative correlation between the growth dynamics of investments in infrastructure and the fleet of aircraft, which would encourage enterprises to eliminate this disproportion in terms of the development of their material and technical basis.

$$d_{21} > d_{22}. \tag{3}$$

Thus, based on the logical conclusions and operational cost analysis, there was obtained a regulatory rank rating consisting of 12 indicators, Table I.

TABLE I

STANDARD RANKING RATING OF INDICATORS

Factor	Sub-factor	Indicators	Rank
D_1	1.1	Flight safety, d_{11}	1
	1.2	Coerced tonne-kilometre, d_{12}	2
D_2	2.1	General investments in infrastructure, d_{21}	3
	2.2	General investments in the aircraft fleet, d_{22}	4
D_3	3.1	Lubricants: oil and greases (consumables), d_{31}	5
	3.2	Aircraft fleet depreciation (amortization), d_{32}	6
	3.3	Maintenance and repair of aircraft, d_{33}	7
	3.4	Flight crew salary, d_{34}	8
	3.5	Technical personnel salary (engineers), d_{35}	9
	3.6	Salary of other airline employees, d_{36}	10
	3.7	Unforeseen expenses, d_{37}	11
	3.8	General production expenses on the technical basis, d_{38}	12

At the same time, we should take into consideration that the normative rank series is more promising – the airline should be oriented towards it. In practice, in the process of aircraft operation in a certain period of time, some actual order of motion of these indicators is formed and an actual rank number is created. Naturally, the actual rank rating may differ from the normative one due to operational circumstances. Moreover, the normative interrelation can be achieved by different methods. In other words, the normative interrelation can correspond to a whole lot of actually developing ratings of indicators. From this follows the need to measure the degree of deviation of the actual rating of the quality model parameters from the standard (reference) one. For the quantitative expression of the non-conformity measure between the actual and normative rank orders reflecting the volume side of this non-conformity, the rank correlation is used in mathematical statistics, the value of which in our case is an internal characteristic, as it captures the effect of the change of each element of the system (or the value of the indicator) at the level of the final useful result in the production process; so its value will actually reflect the level of the quality of the airline's operation or the level of the quality of tasks (with safety taken into account) performed by the airline, if the terminology of the theory of quality is used [10].

IV. DEVELOPMENT OF A METHODOLOGY FOR ASSESSING THE MEASURE OF NON-CONFORMITY BETWEEN THE ACTUAL AND NORMATIVE RANKING ORDER OF INDICATORS

The proposed method has been approbated on an airline performing charter flights to airports in Europe, Asia and Africa, as well as providing services for the transportation of VIP customers. An integrated management system was used to manage the operation of the airline [10], [13]. All the initial data for the solution of this task have been taken from the Airline Information Management System of AIMS, which takes into account and stores all the necessary data flow for the risk analysis, data on the volume of the performed work and data characterizing the operating conditions of aircraft, for example, the state of the surrounding environment (meteorological conditions, ornithological situation, intensity of air traffic, etc.). The presentation of all data in AIMS is differentiated by aircraft types, aircraft classification, types of aircraft application (use), causes of adverse events, types of events, flight stages, airline services, etc. A calculation of performance indicators on the basis of statistical data of one aircraft type – Airbus A320 – has been carried out based on their performance for the period 2011 to 2015 [13]–[15].

The results of the calculations are shown in Table II.

TABLE II

RESULTS OF CALCULATIONS

Group of Factors	Subgroups of Factors	Actual Movement Index	Normative rank (Reference)	Actual Rank Indicator	Deviation	Deviation Square	Actual Movement Index	Normative Rank (Reference)	Actual Rank Indicator	Deviation	Deviation Square
		2011–2012					2013–2014				
D_1	1.1	–0.124	1	12	–11	121	1.000	1	12	–11	121
		0.733	1	11	–10	100	0.767	1	12	–11	121
	1.2	3.138	2	7	–5	25	5.211	2	6	–4	16
		5.690	2	7	–5	25	8.300	2	5	–3	9
D_2	2.1	1.995	3	9	–6	36	5.267	3	5	–2	4
		4.956	3	9	–6	36	6.657	3	9	–6	36
	2.2	–0.28	4	11	–7	49	1.938	4	1	–7	49
		0.715	4	12	–8	64	2.127	4	10	–6	36
D_3	3.1	2.718	7	8	1	1	4.938	7	9	–2	4
		5.229	7	8	–1	1	7.868	7	6	1	1
	3.2	3.215	6	6	0	0	5.773	6	4	2	4
		5.919	6	5	1	1	8.682	6	4	2	2
	3.3	4.611	8	3	5	25	7.431	8	2	6	36
		6.917	8	2	–6	36	8.848	8	3	5	25
	3.4	6.633	5	2	3	9	3.489	5	10	–5	25
		2.848	5	10	–5	25	1.270	5	11	–6	36
	3.5	3.811	9	4	5	25	5.023	9	8	1	1
		6.627	10	3	7	49	7.171	10	8	2	4
	3.6	1.946	12	10	2	4	5.810	12	3	9	81
		5.769	11	6	5	25	7.225	12	7	5	25
	3.7	7.312	11	1	10	100	9.899	11	1	10	100
		11.576	12	1	11	121	12.83	11	1	10	100
	3.8	3.532	10	5	5	25	5.177	10	7	3	9
		6.222	9	4	5	25	12.010	9	2	7	49

As it can be seen, the dynamics of changes in the performance indicators reflect a disproportionate process of airline functioning. Some factors develop in the direction of the normative ratings while others develop in the opposite direction. This leads to fluctuations in the flight safety level in both upward and downward directions.

The study of the dynamics of indicator change makes it possible to obtain important information about the proportions of changes in productive-economic factors at the expense of which the given quality level of transport products was ensured.

The reduction of the level of flight safety and the negative value of its index may primarily be caused by imbalances in the distribution of investments between the infrastructure of the airline and the aircraft fleet.

In the process of production of transport products, this, to some degree, causes an excessively high rate of growth of self-costs of separate items and groups of items 3.3–3.8 (“Current overhaul of aircraft”), 3.4 (“Flight crew salary”), 3.5 (“Technical staff salary”), 3.6 (“Salary of the rest of the ground staff"), 3.8 (General Production Services), that is the discrepancy between the dynamic indicators D_{21} and D_{22} caused an excess increase in costs for indicators D_{35}, D_{36} ,D_{38} the connection of which with the level of safety was expressed in that for the technical reasons of the enterprise in 2011–2014. There were quite a lot of technical occurrences.

As seen from Table 4.3, it is not necessary to talk about optimal economic conditions in the calculated years in this airline. Thus, in 2011 and 2012 the level of flight safety, instead of the first rank, moved to ranks12 and 11 respectively. In 2013, it moved back to the first rank; however, in the following year it again fell down to rank 12. This is explained by the fact that in 2011 and 2012 investments in the aircraft fleet occupy the ranks that are directly opposite to flight safety; while in 2013, this indicator corresponds to the normative ratings, beside that the indicator characterizing the salary of the flight crew stands above the normative ratings. All this provided a higher level of flight safety in this year, which confirms the accuracy of the proposed model.

V. Conclusion

1. In general, the research made it possible to identify, in the most general form, the mechanism of the influence of production and economic conditions and factors on the flights safety.
2. Research of degree of disparity of actual correlation of D_1, D_2, D_3 to normative, by the analysis of degree of mobility of separate indexes, which allows to deduct the separate groups of industrial and economic factors that in a most in degree have influence on the origin of disproportion in the dynamics of change of D_2, D_3 and consequently on the industrial and economic environment of air transport product with certain strength of flights safety.
3. It is recognised that the mechanism of the influence of production and economic conditions and factors on the process of creating safe transport products, first: gives an idea of the directions of strengthening the material and technical base of the airline, i.e. allows to make reasonable economic decisions in the allocation of capital investments; second: it allows to develop specific measures to improve the activities of the airline's services, based on the condition for improving flight safety.
4. Assessing the level of the quality of the operation of an airline, taking into account the level of safety, are sufficiently sensitive, informative and reliable.

VI. References

[1] L. Liepa, *Kvalitātes vadības sistēma*. Biznesa partneri, 2016.
[2] E. Lilienfelde and V. Šestakovs, "Quality Assurance Systems for Civil Aviation," *Transport. Aviation Transport*, vol. 27, pp. 362–366, 2008. ISSN 14078015
[3] *ISO 9000, ISO 14000 Kvalitātes nodrošināšanas sistēma*. [Online]. Available: www.iso.ch. Accessed on: January 22, 2018.
[4] IATA, *IOSA Standard Manual*, 2012.
[5] C. V. Oster, J. S. Strong, and C. K. Zorn, *Why Airplanes Crash: Aviation Safety in a Changing World*. Oxford, 1992.
[6] A. Merritt and J. Klinect, "Defensive Flying for Pilots: An Introduction to Threat and Error Management," *The University of Texas Human Factors Research Project*, The LOSA Collaborative, 2006.
[7] Boeing Accident Map Aviation Safety Network, *Statistical Summary of Commercial Jet Airplane Accidents, 1959–2008*. [Online]. Available: http://aviation-safety.net/statistics/geographical/worldmap.php?year=2008. Accessed on: December 13, 2017.
[8] R. Bogdane, A. Vaivads, and D. Dencic, "Evaluation of Management System Effectiveness in the Preparation of the Aircraft for Flight in Faulty Conditions," *Transport and Aerospace Engineering*, vol. 2, no. 1, Jan. 2015. https://doi.org/10.1515/tae-2015-0002
[9] J. H. Weiss and M. E. Gershon, *Production and Operations management*. Boston: Allyn and Bacon, 1993.
[10] R. Bogdane, V. Šestakovs, and D. Dencic. "Development of the Mathematical Model of Integrated Management System for an Airline," *Transport and Aerospace Engineering*, vol. 3., no. 1, pp. 44–51, Jan. 2016. ISSN 2255968X. e-ISSN 22559876. https://doi.org/10.1515/tae-2016-0006
[11] N. M. Zvorykin. "Realizacia processnogo podhoda na promyšlennom predpriatii," *Metody menedzmenta kacestva*, no. 1, pp. 35–40, 2004.

[12] R. Šneidere. *Finanšu analīzes metodes uzņēmuma maksātnespējas prognozēšanai*. Lietišķās informācijas dienests, 2009. ISBN 9789984826264
[13] R. Bogdane, *Safety News. SAFA inspections and findings in first quarter of 2013 and 2014*. Riga: SmartLynx Airlines, 2014.
[14] ICAO, *Globālais lidojumu drošības plāns*, 2007.
[15] ICAO, *Safety Management Manual (SMM)*, Doc 9859 AN/474, 2013.

Ruta Bogdane, Doctoral student of the Institute of Aeronautics, Riga Technical University.
2001 – Engineer's degree in telecommunications, Riga Technical University.
2005 – Master of Business Administration, Business High School of Turība.
2013 – Master degree in Aviation Transport, Riga Technical University.
Work experience: 2004–2008 Quality Manager, Civil Aviation Agency of Latvia. 2008 to present time, Compliance Monitoring Manager (AIR OPS, Part M, Part FCL), SIA "SmartLynx Airlines".
Her fields of research: airworthiness, commercial aviation, management efficiency, quality management.
Address: Institute of Aeronautics, Faculty of Mechanical Engineering, Transport and Aeronautics, Riga Technical University, Lomonosova 1A, k-1, Riga, LV-1019, Latvia.
Phone: +371 28377793
E-mail: Ruta.Bogdane@gmail.com

Aleksandrs Bitiņš, Doctoral student of the Institute of Aeronautics, Riga Technical University.
1999 – Mobile Infantry Platoon Commander, National Defence Academy of Latvia.
1999 – Bachelor degree in Aviation Transport, Riga Aviation University.
2002 – Engineer's degree in Aviation Transport, Riga Technical University.
Work experience:
1999–2009 – Engineer at Latvian Air Force. Maintenance of Airplanes and Helicopters.
2011–2018 – Senior Compliance Monitoring Officer, SIA "SmartLynx Airlines". Company compliance with ICAO, EASA, IOSA standards.
Address: Institute of Aeronautics, Faculty of Mechanical Engineering, Transport and Aeronautics, Riga Technical University, Lomonosova 1A, k-1, Riga, LV-1019, Latvia.
Phone: +371 29199659
E-mail: aleksandrs.bitins@hotmail.lv

Vladimirs Šestakovs, was born in 1938 in Voronezh region, Russia.
He graduated from the Riga Institute of Civil Aviation Engineers in 1963, Technical Operation of Aircraft and Engines. Professor, Doctor of Engineering Sciences (Dr. habil. sc. eng.).
Education: Riga Civil Aviation Engineering Institute, Mechanical Engineer (1963), Doctoral Degree in Aviation Leningrad Civil Aviation Academy (1984), Doctor Habilitus Degree in Engineering (1992), Full Member of the International Academy of Ecology and Safety of Vital Functions (1994).
Research interests: professional air transport operation, flights safety, ecology and life protection, ecologically pure non-traditional kinds of transport.
Address: Institute of Aeronautics, Faculty of Mechanical Engineering, Transport and Aeronautics, Riga Technical University, Lomonosova 1A, k-1, Riga, LV-1019, Latvia.
Phone: +371 67089990
E-mail: sheatakov@inbox.lv

Yasaratne Bandara Dissanayake, Mg. sc. eng., graduated from Riga Aviation University in 1992 and completed MSc in 1994. In 2000, joined the research group of Prof. Vladimirs Šestakovs on various researches related to flight safety and has more than 20 years of experience in the aviation sector. Work experience: Head of the Office of Airworthiness, Design Compliance Verification Engineer (CVE) for Aircraft Structures & Interiors in an EASA approved Design Organization (DOA) – Stansted Airport, United Kingdom.
Address: 80, Brunel House, St. James Road, Brentwood, Essex, England, CM14 4EL
Phone: +44(0)1279 297 000
E-mail: yasaratne@knsi.co.uk