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APPLICATION OF THE MULTIDIMENSIONAL STATISTICAL ANALYSIS IN THE DEVELOPMENT OF AN INTEGRATED SAFETY MANAGEMENT SYSTEM IN AN AIRCRAFT MAINTENANCE ORGANIZATION

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Modern aviation enterprises are lots of risks-related owners associated with execution of their activities. Nowadays there are various management systems such as a Quality Management System (QMS), Safety Management System (SMS), etc., which describe all the potential risks for an organization. The problem of synchronization and unification of these systems in the framework of a comprehensive analysis of managing changes and fulfilling production operation remains unsolved at this point. To settle this problem, the article suggests using an integrated safety management system (ISMS). When developing ISMS in an aircraft maintenance organization that integrates the management systems of flight safety, quality, aviation, information, environmental safety, etc., the organization encounters the problem of data redundancy and duplication about manifestations of hazard factors in various aspects of its activities. This can make it difficult to collect and process data and take corrective/preventive measures. The issue of reasonable reduction of the original list of hazard factors can be considered as the subject of decreasing the dimension of the entity activity model, which can be solved using the method of the factor analysis principal components. Furthermore, application of the principal components method provides an expert analyst with supplementary, scientifically-based data on the quality of work and allows him to predict trends. The article based on real data of the aircraft maintenance organization shows the applicability of the method with the purpose for optimizing the list of hazard factors manifestations regarding a single aspect of organization activity.

Key words: integrated management system, flight safety, hazard factor, method of principal components, decreasing the model dimension, system integration.

INTRODUCTION

The general approach to ensure techno genic safety proposes a hazard analysis and consideration in various aspects of the entity activity [1]. A modern concept of aviation-transport system safety management as a conventional complex “socio-technical system” [2] is based on the integration of various management systems.

In terms of an aircraft enterprise it is primarily the system of flight safety management (SMS), quality management system (QMS), aviation safety system (SAS) and the systems of labor health protection. These systems are developed, implemented and function in enterprises – aviation services suppliers in compliance with the regulatory requirements.

The significance of the information security system is increasing.

The conceptual provisions to assess risks associated with this aspect of activity are specified in the Russian National Standard[1]. Due to rapid aircraft computerization, its security vulnerability to acts

[1] National Standard R 57240-2016. Aviation Activity Safety Management in Civil Aviation. Main Provisions. M.: Standard-inform, 2020. 20 p.

of unlawful interference is increasing, which can have the most far-reaching repercussions for a flight safety. Meanwhile, in Russian civil aviation, as the report "The Concept to Ensure Information Security of Aircraft Hardware. FSUE AS Research"[2] states, the requirements to provide information security are not yet available.

Other actively developing systems to manage safety have been of vital importance lately. First and foremost, it is Enterprise Resource Planning (ERP) that is interpreted as "planning of enterprise resources". This program is becoming a specific enterprise strategy that will take into account management of different spheres: finance, human resources, assets, collaboration with partners, recording the detailed history of operations with customers [3]. It is significant to solve "dilemma of two P" – "Production-Protection"[3] – more reasonable allocation of resources between safety and production development.

The systems Customer Relationship Management (CRM) of management of mutual relations with customers, that allow the enterprise to optimize business processes, are simultaneously implemented. The key component of the given approach is the special software to manage work, monitor customers' actions and communication automation [4]. Partners and customers of the aircraft maintenance enterprise are, essentially, aircraft operators, relationships with which are of importance for flight safety.

The concept of the integrated system is not new. As far back as in 2007 the International Air Transport Association (IATA) introduced IASM abbreviation (Integrated Airline Management System) in its Guidance[4]. It is suggested to use ISMS abbreviation (Integrated Safety Management System) for the integrated system of aircraft enterprise safety management. Such a system must conceptually incorporate 8 constituents (fig. 1).

Fig. 1. Integrated Safety Management System

It is obvious that processing of miscellaneous data array will be required for this system functioning. Optimization of the procedures for collecting and first-time data processing is a crucial task and may be provided by means of multidimensional statistical methods, in particular, the method of the factor analysis principal components. The utilization of the method is shown on the example of implementing the integrated system of safety management in the aircraft maintenance enterprise.

[2] Conference "Information Cyber Security". Moscow, 2018.
[3] Guidance about Flight Safety Management, 4th Edition // ICAO, 2018. 150 p.
[4] Integrated Airline Management System for Air Transport Operation // IATA, Ed. 2007. 7 p.

RESEARCH METHODS AND METHODOLOGY

Approach to the formation of the safety level objectives and indexes in ISMS of aircraft maintenance enterprise

Among the listed above safety systems, the flight safety management system (SMS) have been comprehensively adopted by airlines and aerodrome operators, therefore, while developing ISMS it is advisable to rely on this experience. Various approaches, the principles of systems design and operation within the framework of ICAO ISMS, are given in a variety of works, for instance [5–8].

Relying on this experience, it is expedient to outline objectives primarily targeted at flight safety and quality on the first stage of ISMS development. For example, the following goals were declared in one of the aircraft maintenance enterprises:

- to reduce the number of all the types of aviation events through the personnel's fault by 50% at least, compared with the last year's indexes;
- to reduce the number of irregularities while conducting maintenance and components repair by 20%, compared with the last year's indexes;
- to reduce the number of claims from customers by 15%,compared with the last year's indexes;
- to reduce the number of detected discrepancies in the course of external audits by 10%, compared with the last year's indexes;
- to monitor ISMS effectiveness by means of audits and monthly control of the indexes as well as by risks assessments- implementation of the program for safety guarantee;
- to guarantee conformance of the company's activity in line with the Russian and International Standards in the field of flight safety-implementation of the program for safety guarantee;
- to cultivate the culture of safety and develop the system of voluntary messages.

Further on, it is supposed to add the objectives referring to other ISMS constituents to the list.

On the basis of the objectives, the enterprise constructs indexes – Safety Performance Indicator (SPI), appropriate for SMART principles (Specific-Measurable-Achievable-Relevant Time bound) i.e. particular, measurable, achievable, reliable and time bound. It is relevant to the implementation of constituent 3 of ICAO ISMS conceptual framework "flight safety guarantee" (more correct term "confirmation of flight safety level" [9]).

Relative quantitative indexes are suggested as the top level SPI in the organization: Qae – aviation events; Qde – defects list; Qcl – claims from customers; Qaud – shortcomings during external audits. All the characteristics are calculated according to a single formula:

$$К = \frac{N}{n} \cdot 1000, \quad (1)$$

where N – number of aviation events, defects list, claims or discrepancies:

n – volume of conducted jobs in man-hours.

Asymptotic values of these indexes for the current year are defined.

The root of the problem while implementing ISMS in the aircraft maintenance enterprise is objectivity of the original information. It is difficult to reveal accurately various contraventions on the every process step, since capabilities of using means of objective supervision are limited. There is also an issue of incomplete coverage of production supervision. Another difficulty is associated with their classification and bringing into conformity with uniform standards and wordings for further processing.

The given technique is used in this enterprise. In order to achieve the goals to be sought, low level SPI (these SPI are called "factors of conditional risk") for 11 aspects of activity are constantly calculated:

1. LEG-legal coverage;
2. SAL-planning and sales;
3. ORG-organization of production;
4. FIN-finance, accountancy;
5. DOC-technical and working documentation;
6. REC- records keeping and storage;
7. SCH- logistics support and warehousing;
8. STF-staff;
9. TLE-tools and equipment;
10. FAC-facilities;
11. ENV-environment.

Source data for calculations of these SPI comes from the following items:

- a defects list;
- representation of coupons;
- notes for reports of internal and external audits;
- results of conducted events investigations;
- compulsory and voluntary messages of employees.

The one-year monitoring diagram of such a “conditional risk” for the line of activity “DOC-technical and working documentation” is presented in Figure 2.

Targeted $К_{Ц}$ and threshold levels $К_{П-1.2.3}$ are calculated on the basis of observations over the previous years in accordance with ICAO SMM recommended guideline, 4th ed., 2018.

$$K_{Cр} = \frac{\sum_{i=1}^{n} K_R}{n};\ K_{Ц} = 0{,}95 K_{Cр}$$
$$K_{П-1} = K_{Ц} + \sigma;\ K_{П-2} = K_{Ц} + 2\sigma;\ K_{П-3} = K_{Ц} + 3\sigma;$$
$$\sigma = \sqrt{\frac{\sum_{i=1}^{n} (К_{Cр} - К_i)^2}{n-1}}.$$

Within the analysis of each aspect of activity a list of factors contributing to hazard, such as characteristics of response or lack of response, circumstances, conditions or their combination, that have an effect on flight safety, work efficiency and quality, conditions of employment, was drawn up.

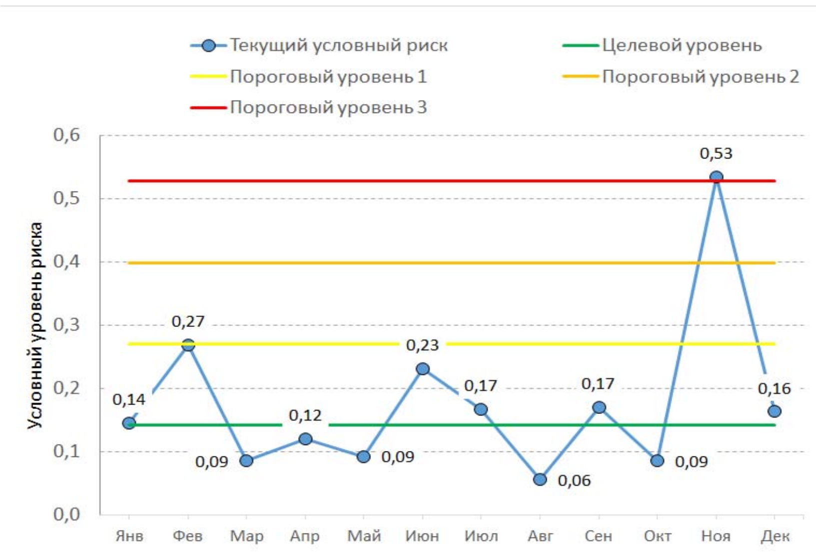

Fig. 2. Level 2 SPI monitoring (“conditional risk”) for DOC activity aspect

The lists of factors contributing to hazard were itemized on the basis of the expert survey on the appropriate branches of activity. The number of factors contributing to hazard concerning the aspects in the formed lists varies from 5 to 48. An actual task to optimize these lists exists.

Optimization of the hazard factors list

In order to solve this problem it is proposed to employ the method of the factor analysis principal components.

The purpose of the principal components method [10] is to reduce the number of components for the random vector of the organisation state (in terms of reducing its space dimension), that can be possible without substantial data loss about the system under study contained in the given observations.

The problem is formulated as follows: using materials of n observations one should replace a set of m hazard factors of Z source data for a smaller number k < m of standardized orthogonal factors or constituents presenting themselves the most essential latent factors.

The matrixing model of the component analysis is suggested as:

$$\boldsymbol{Z} = \mathbf{W} \cdot \mathbf{F},$$

where $\boldsymbol{Z} = (Z_1, Z_2 \dots Z_n)$ – random standardized vector of original source data;

$\boldsymbol{F} = (\boldsymbol{F_1}, \boldsymbol{F_2} \dots \boldsymbol{F_n})$ – vector of factors;

W – matrix of factor loads.

W matrix is calculated from the matrix eigenvalues and eigenvectors of correlation matrix of R source data from the relation:

$$\boldsymbol{R} = \mathbf{W} \cdot \mathbf{W}^{\mathbf{T}}.$$

Based on research to employ this method in the aviation sphere let us note the paper [11], which considers the issues of prognostics and prevention of aviation occurrences, using an array of data. The factor analysis is utilized in conjunction with the method of Bayesian network of credit. More than 60 types of aviation occurrences are considered. The step prognostics detailed methodology on the different stages of flight is given. The approach is distinctly notable from prognostics by means of trends related with "background data". It allows us to take into account the system deficiencies. However, an attempt to solve such a global task can be faced with a problem of a sufficient amount of source data.

The paper [12] gives a practical illustration of using the factor analysis to process the results of the safety and quality audit in the aircraft maintenance enterprise. The given approach can be utilized for solving the assigned task as well.

The practical implementation of the method is proposed using the example of actual data of the same aircraft maintenance enterprise. A software package "STATISTICA-7", its description in the Guidance [13] as well as the methodology of the practical application of the factor analysis from the electronic book [14] is used.

Source data are monthly – recorded of 16 hazard factors manifestations with respect to the activity aspect of STF-Staff and volume of work in man-hours over the period of January 2018 – March 2021 (39 values). Thereupon, relative indexes for each hazard factor per each month are calculated as:

$$X_{ij} = \frac{N_{ij}}{n}, \tag{2}$$

where:

N_{ij} – the number of factors contributing to hazard manifestations;

n – volume of work in man-hours per month, $i = \overline{1,16}$; $j = \overline{1,39}$.

Table 1 illustrates the source data fragment.

Table 1

Source data table fragment

№ п/п	Hazard factors		Variable designation in STATISTICA	2018					
				January		February		March	
				Nij	Xij	Nij	Xij	Nij	Xij
				j = 1		j = 2		j = 3	
1	STF08.13	Violation of the technology when conducting work, failure to comply with operational and technical documentation	S-13	1	1,9E-05	2	4,3E-05	0	0,0E+00
2	STF08.03	Errors when conducting maintenance work	S-03	0	0,0E+00	1	2,1E-05	2	3,8E-05
3	STF08.15	Erroneous use of MEL category	S-15	0	0,0E+00	0	0,0E+00	0	0,0E+00
4	STF08.30	Loss of tools/equipment during maintenance	S-30	0	0,0E+00	0	0,0E+00	0	0,0E+00
5	STF08.47	Absence of or incompletely conducted check/inspection	S-47	0	0,0E+00	2	4,3E-05	1	1,9E-05
6	STF08.31	Breakage or damage to tools/equipment during maintenance	S-31	0	0,0E+00	0	0,0E+00	0	0,0E+00
7	STF08.17	Violation of the technology of components replacement	S-17	1	1,9E-05	0	0,0E+00	0	0,0E+00
8	STF08.28	Damage to the component during maintenance	S-28	0	0,0E+00	0	0,0E+00	0	0,0E+00
9	STF08.25	Use of unauthorized tools/equipment during maintenance	S-25	0	0,0E+00	0	0,0E+00	0	0,0E+00
10	STF08.08	Lack of personnel of the appropriate category to accomplish a task	S-08	0	0,0E+00	0	0,0E+00	0	0,0E+00
11	STF08.05	Authorization of not certified personnel to conduct work	S-05	0	0,0E+00	0	0,0E+00	0	0,0E+00
12	STF08.24	Use of faulty tools/equipment during maintenance	S-24	0	0,0E+00	0	0,0E+00	0	0,0E+00
13	STF08.38	Notes to isolate a fault in case of repeated failure	S-38	0	0,0E+00	0	0,0E+00	0	0,0E+00
14	STF08.12	Flight delay/cancellation through personnel's fault	S-12	0	0,0E+00	0	0,0E+00	0	0,0E+00

Continuation of Table 1

15	STF08.16	Improper fault isolation	S-16	0	0,0E+00	0	0,0E+00	0	0,0E+00
16	STF08.26	Damage to an aircraft during maintenance	S-26	0	0,0E+00	0	0,0E+00	0	0,0E+00
Tj Volume of conducted works (man-hours)					52163		46829		53070

You can see that the big number of zero values for variables is the feature of data array. It led to the exclusion of two variables of S-24 and S-38 while building "STATISTICA" correlation matrix (the first stage of the analysis).

The stated below analysis is fulfilled for the 14th-dimensional vector. The problem is to reduce its dimension without a substantial loss of variability.

The plot of eigenvalues of the principal components is shown in Figure 3.

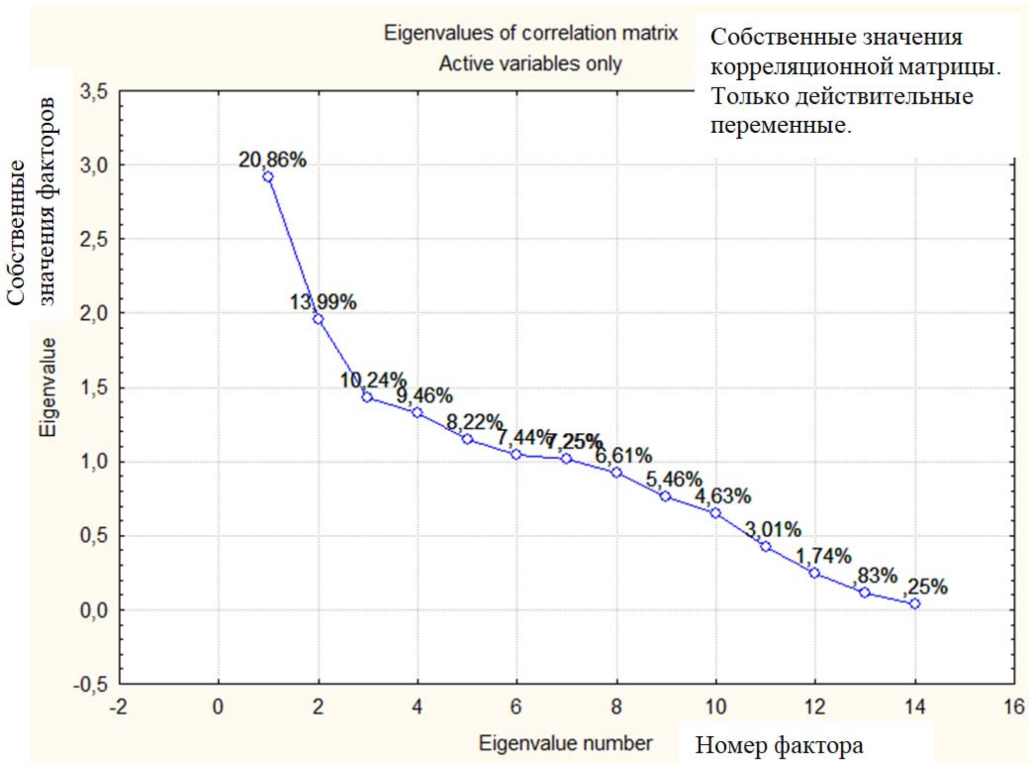

Fig. 3. Plot of eigenvalues factors

In order to define how many factors to leave for the further analysis, let us use the most general recommendation from [14]: to retain those whose eigenvalues exceed 1. Such factors are 7. It means that if the factor does not separate out variance equivalent, at least, to the single variable variance, in this case it is omitted. As indicated in Figure 4, almost 77,5% of total variance of the original 14th–dimensional vector is concentrated in 7 principal components.

Eigenvalues (Исх. Данные.sta) Extraction: Principal components				
Value	Eigenvalue	% Total variance	Cumulative Eigenvalue	Cumulative %
1	2,920118	20,85798	2,92012	20,85798
2	1,958175	13,98697	4,87829	34,84495
3	1,433330	10,23807	6,31162	45,08302
4	1,325039	9,46456	7,63666	54,54758
5	1,151486	8,22490	8,78815	62,77248
6	1,041816	7,44154	9,82996	70,21403
7	1,015643	7,25460	10,84561	77,46862

Fig. 4. Eigenvalues and total variances of 7 principal components

For the further analysis let us select the method of the coordinate system rotation providing the highest level of consistency of the source factors and principal components. As is known, the principal components method allows us to execute the "selection" of the orthogonal coordinates systems in space of any dimension. It is recommended to select a particular position of the axes-coefficients under which the biggest number of source vectors projections close to zero or one unit ("simple" structure of loads) [14] is achieved.

In this case the method, maximizing variance of source "raw" data Varimax Raw", is selected from 8 variants of rotation specified in the program "STATISTICA". The obtained distribution of factor loads on the principal components is shown in Figure 5.

Factor Loadings (Varimax raw) (Исх. Данные.sta) Extraction: Principal components (Marked loadings are >,700000)							
Variable	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5	Factor 6	Factor 7
S-13	0,109605	0,887940	0,047610	-0,211459	-0,138353	-0,058971	0,036501
S-03	-0,235159	0,523980	0,138399	0,179342	0,354844	0,368195	-0,131168
S-15	0,893259	0,003808	0,058886	0,032772	-0,029996	0,042145	0,007321
S-30	0,457584	0,029991	0,701571	-0,219675	-0,065543	-0,019569	-0,114114
S-47	-0,127636	0,080004	-0,156928	-0,756652	-0,020604	-0,012230	0,252898
S-31	-0,067700	-0,098872	0,793418	0,250920	0,084698	0,069656	0,193334
S-17	0,522664	0,296415	0,298743	-0,048896	-0,526527	-0,129953	-0,051541
S-28	0,963303	0,030204	0,107269	0,000539	-0,095618	-0,011438	0,009592
S-25	-0,002915	-0,094367	-0,068198	0,091227	-0,826097	0,153985	0,027559
S-08	0,667438	-0,209596	-0,387997	0,201760	0,287683	0,097965	0,133379
S-05	-0,038868	-0,023545	-0,057451	0,065036	0,013155	0,007237	-0,932741
S-12	-0,050111	-0,027518	-0,016102	0,039740	0,080540	-0,934909	0,000347
S-16	0,000622	-0,119594	0,107228	-0,654015	0,184577	0,122079	-0,156354
S-26	-0,075844	0,822987	-0,145146	0,222641	0,164351	0,087663	0,022567
Expl.Var	2,751868	1,914615	1,463300	1,296227	1,277161	1,093227	1,049209
Prp.Totl	0,196562	0,136758	0,104521	0,092588	0,091226	0,078088	0,074943

Fig. 5. Distribution of factor loads on the principal components

Factor loads are the values of the correlation coefficients for each of the variables with each of the identified principal factors. Accordingly, if factor load exceeds 0.7, it illustrates that this variable is closely related with the factor under consideration. The plot in Figure 6 shows aggregation of source variables with regard to two first components what makes the analysis easier [15].

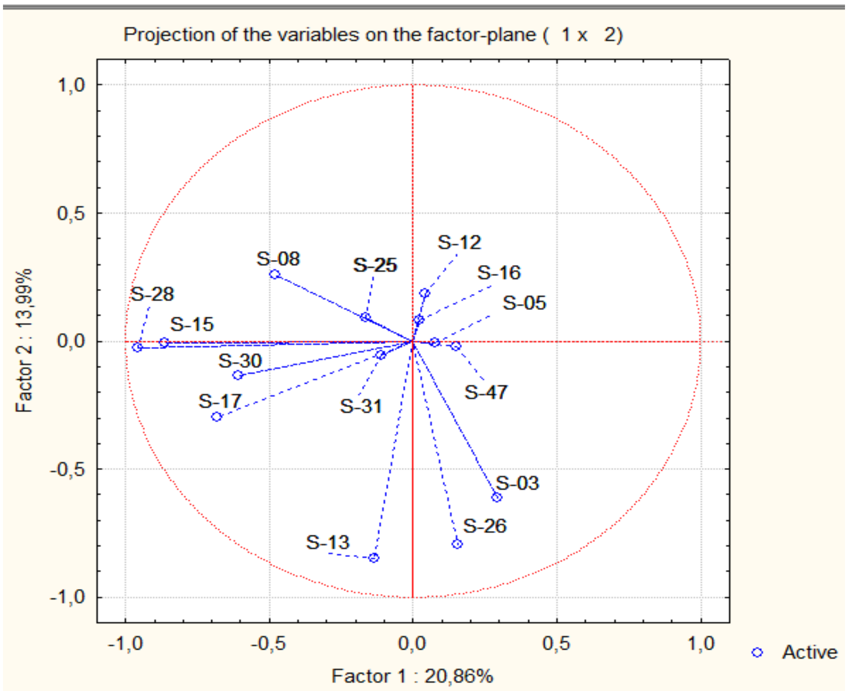

Fig. 6. Projection of the source variables on F_1-F_2 factor plane

RESULTS AND DISCUSSION

The interpretation of the obtained results for application of the principal components method under actual data can be the following.

The principal factor F_1 accounts for 20% of all the loads. Source variables correlate with it to the greatest extent:

S-15 Erroneous use of MEL category;

S-28 Damage to a component when conducting maintenance;

S-08 Lack of personnel of the appropriate category to carry out the mission.

So, factor F_1 can be interpreted as “Erroneous decisions and damage to components due to shortage of qualified specialists”.

Factor F_2 takes over loads of the variables:

S-13 Violation of the technology when conducting work, failure to comply with operational and technical documentation;

S-26 Damage to an aircraft when conducting maintenance.

Accordingly, factor F_2 can be characterized as “Deviations from the technology and operational and technical documentation requirements causing aircraft damage”.

The variables are linked with Factor F_3:

S-30 Loss of instruments/equipment during maintenance (including leaving the instrument in aircraft, engine operation area);

S-31 Breakage or damage to tools/equipment during maintenance.

Factor F_3 can be reasonably called “ Lack of skills to use tools and equipment”.

Factor F_4 has substantial variables loads:

S-47 Absence of or incompletely conducted check/inspection;

S-16 The poor-quality troubleshooting.

Accordingly, the name “Deficiencies while arranging and conducting the supervision of work” is assigned to factor F_4 [16, 17].

New factors F_5, F_6 and F_7 have critical loads merely from one variable (single factor contributing to hazard), so their names will conform to these variables as follows:

F_5 – " Usage of not authorized tools/equipment during maintenance";

F_6 – "Flight delay/cancellation through the fault of personnel";

F_7 – "Authorization of not certified personnel to work".

Thus, the obtained result can be used by ISMS developers to make grounded decisions in order to minimize the original list of factors contributing to hazard concerning the given aspect of activity. It will allow us to considerably facilitate data collection and processing with insignificant loss of their informational value.

Furthermore, revealed amplified factors illustrate availability of hidden causes of hazard factor manifestations what will contribute to development of effective measures to mitigate the risk.

CONCLUSION

Development of the integrated system of safety management (ISMS) for the aircraft maintenance enterprise is a crucial task. In conjunction with the customary constituents (SMS, QMS, SAS, management systems of environment, information, manufacture safety), the management systems that have been developed further lately, such as CRM and ERP, should be integrated into ISMS.

On the first stage it is expedient to take advantage of the SMS, QMS development experience. In order to attain objectives to be sought in the safety sphere, data collection about hazard factor manifestations in the responsive and proactive modes with respect to every aspect of activity, assessment of related risks and development of corrective actions must be arranged in the enterprise.

As the experience showed, the list of such factors contributing to hazard may be redundant, what hinders data collection, processing and analysis.

On the basis of the stated above data of the aircraft maintenance enterprise it is shown that the method of the factor analysis principal components can be employed to optimize the mentioned lists.

Application of the principal components method reveals more general factors contributing to hazard, providing an expert analyst with supplementary, scientifically-grounded data about enterprise safety. Reduction of model dimension enables us to concentrate every effort on prevention of principal and hidden factors impact. It facilitates to distribute more efficiently resources allocated to maintain aircraft airworthiness within the framework of enterprise ISMS.

It should be noted that application of the factor analysis and other innovative data analysis methods does nor replace but adds routine work to ensure aircraft maintenance quality and safety.

REFERENCES

1. **Makhutov, N.A., Pulikovsky, K.B., Shoigu, S.K. and other.** (2008). *Bezopasnost Rossii. Pravovyye sotsialno-ekonomicheskiye i nauchno-tekhnicheskiye aspekty. Analiz riskov i upravleniye bezopasnostyu: Monografiya* [Safety of Russia. Legal socio-economic scientific and technical aspects. Risk analysis and security management: Monograph]. Moscow: MGF "Znaniye" im. akademika K.V. Frolova, 527 p. (in Russian)

2. **Leveson, N.G.** (2011). *Engineering a safer world. Systems thinking applied to safety*. London, The MIT Press, 560 p.

3. **Mabert, V.A. and Watts, C.A.** (2005). *Enterprise applications: building best-of-breedsystems*. In book: Strategic ERP. Extension and use. Stanford: Standofrd University Press, chapter 4, p. 52–70.

4. **Zamil, A.M.** (2011). *Customer relationship management: a strategy to sustain the organization's name and products in the customers' minds*. European Journal of Social Sciences, vol. 22, no. 3, p. 451–459.

5. **Lushkin, A.M.** (2017). *Typical safety management system of an operator in the Russian Federation*. Civil Aviation High Technologies, vol. 20, no. 1, p. 8–16. (in Russian)

6. **Nisula, J.** (2010). *The ARMS methodology for operational risk assessment in aviation organisations*. SKYbrary, 67 p. Available at: https://www.skybrary.aero/bookshelf/books/1141.pdf (accessed: 01.03.2021).

7. **Sharov, V.D., Vorobyov, V.V. and Zatuchny, D.A.** (2021). *Risk management methods in the aviation enterprise*. Springer Singapore, 214 p. DOI: 10.1007/978-981-33-6017-4

8. **Tolstykh, S.A. and Sharov, V.D.** (2018). *Method of SMS basic elements development for the aerodrome operator*. Civil Aviation High Technologies, vol. 21, no. 4, p. 29–38. DOI: 10.26467/2079-0619-2018-21-4-29-38 (in Russian)

9. **Sharov, V.D., Eliseev, B.P. and Vorobyov, V.V.** (2019). *Analysis of deficiencies in the procedures for the risk management of safety in the ICAO documents*. Civil Aviation High Technologies, vol. 22, no. 2, p. 49–61. DOI: 10.26467/2079-0619-2019-22-2-49-61 (in Russian)

10. **Jolliffe, I.T.** (2002). *Principal component analysis*. New York, Springer, 488 p. DOI: 10.1007/b98835

11. **Xiaomei, N., Huawei, W., Changchang, C., Jiyu, H. and Zhongdong, S.** (2019). *Civil aviation safety evaluation based on deep belief network and principal component analysis*. Safety Science, vol. 112, p. 90–95. DOI: 10.1016/j.ssci.2018.10.012

12. **Sharov, V.D., Vorob'ev, V.V., Nikolaikin, N.I., Kuznetsov, V.L. and Tolstykh S.A.** (2020). *Methodology for estimating the safety and quality of the aviation service provider activities using the principal component analysis*. Russian Aeronaut, vol. 63, no. 4, p. 575–585. DOI: 10.3103/S1068799820040030

13. **Borovikov, V.P.** (2003). *STATISTICA. Iskusstvo analiza dannykh na kompyutere. Dlya professionalov* [The art of computer data analysis. For professionals]. 2nd ed. (+ CD). St. Petersburg: Piter, 700 p. (in Russian)

14. **Glendon, A.I., Clarke, S.G. and Mckenna, E.F.** (2006). *Human safety and risk management*. 2nd ed. Florida, CRC Press, 528 p. DOI: 10.1201/9781420004687

15. **Kuklev, E.A.** (2007). *Automisation of technological processes of risk's control in the fight safety system*. Nauchnyy Vestnik MGTU GA, vol. 122, p. 37–44. (in Russian)

16. **Wang, Y.C.** (2018). *Prediction of engine failure time using principal component analyses, categorical regression tree and back propagation network*. Journal of Ambient Intelligence and Humanized Computing. DOI: 10.1007/s12652-018-0997-7 (accessed: 03.03.2021).

17. **Voicu, I., Panaitescu, F.V., Panaitescu, M., Dumitrescu, L.G. and Turof, M.** (2018). *Risk management with bowtie diagrams*. IOP Conference Series: Materials Science and Engineering, vol. 400, issue 8, 6 p. DOI: 10.1088/1757-899X/400/8/082021 (accessed: 03.03.2021).

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ПРИМЕНЕНИЕ МНОГОМЕРНОГО СТАТИСТИЧЕСКОГО АНАЛИЗА ПРИ РАЗРАБОТКЕ ИНТЕГРИРОВАННОЙ СИСТЕМЫ УПРАВЛЕНИЯ БЕЗОПАСНОСТЬЮ В ОРГАНИЗАЦИИ ПО ТЕХНИЧЕСКОМУ ОБСЛУЖИВАНИЮ ВОЗДУШНЫХ СУДОВ

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Современные авиационные предприятия являются владельцами множества рисков, связанных с осуществлением их деятельности. На данный момент существуют различные системы управления, такие как система менеджмента качества (СМК), система управления безопасностью полетов (СУБП) и подобные, в которых описываются все возможные риски для предприятия. Проблема синхронизации и единства этих систем в рамках комплексного анализа управления изменениями и осуществления производственной деятельности является нерешенной до сих пор. Для решения этой задачи в статье предполагается использовать интегрированную систему управления безопасностью (ISMS). При разработке ISMS в организации по техническому обслуживанию воздушных судов (ТО ВС), объединяющей системы управления безопасностью полетов, качеством, авиационной, информационной, экологической безопасностью и другие системы, эта организация сталкивается с проблемой избыточности и дублирования информации о проявлениях факторов опасности в различных аспектах ее деятельности. Это может затруднить сбор и обработку данных и принятие корректирующих/предупреждающих мероприятий. Задача по обоснованному сокращению исходного перечня факторов опасности может рассматриваться как задача снижения размерности модели деятельности предприятия, которая может быть решена с помощью метода главных компонент факторного анализа. Кроме того, применение метода главных компонент обеспечивает эксперта-аналитика дополнительными, научно обоснованными данными о качестве работы и позволяет прогнозировать тенденции. В статье на реальных данных организации по техническому обслуживанию воздушных судов показана применимость метода для оптимизации перечня проявлений факторов опасности по одному из аспектов деятельности организации.

Ключевые слова: интегрированная система управления, безопасность полетов, фактор опасности, метод главных компонент, снижение размерности модели, объединение систем.

СПИСОК ЛИТЕРАТУРЫ

1. **Махутов Н.А., Пуликовский К.Б., Шойгу С.К. и др.** Безопасность России. Правовые социально-экономические и научно-технические аспекты. Анализ рисков и управление безопасностью: монография. М.: МГФ «Знание» им. ак. К.В. Фролова, 2008. 527 с.
2. **Leveson N.G.** Engineering a safer world. Systems thinking applied to safety. London: The MIT Press, 2011. 560 p.
3. **Mabert V.A., Watts C.A.** Enterprise applications: building best-of-breedsystems // Strategic ERP. Extension and use. Stanford: Standofrd University Press, 2005. Chapter 4. P. 52–70.
4. **Zamil A.M.** Customer relationship management: a strategy to sustain the organization's name and products in the customers' minds // European Journal of Social Sciences. 2011. Vol. 22, no. 3. P. 451–459.
5. **Лушкин А.М.** Типовая система управления безопасностью полетов эксплуатанта воздушных судов России // Научный Вестник МГТУ ГА. 2017. Т. 20, № 1. С. 8–16.
6. **Nisula J.** The ARMS methodology for operational risk assessment in aviation organisations [Электронный ресурс] // SKYbrary. 2010. 67 p. URL: https://www.skybrary.aero/bookshelf/books/1141.pdf (дата обращения: 01.03.2021).
7. **Sharov V.D., Vorobyov V.V., Zatuchny D.A.** Risk management methods in the aviation enterprise. Singapore: Springer, 2021. 214 p. DOI: 10.1007/978-981-33-6017-4

8. **Толстых С.А., Шаров В.Д.** Метод разработки основных элементов СУБП оператора аэродрома // Научный Вестник МГТУ ГА. 2018. Т. 21, № 4. С. 29–38. DOI: 10.26467/2079-0619-2018-21-4-29-38

9. **Шаров В.Д., Елисеев Б.П., Воробьев В.В.** Анализ недостатков в описании процедур управления риском безопасности полетов в документах ИКАО // Научный Вестник МГТУ ГА. 2019. Т. 22, № 2. С. 49–61. DOI: 10.26467/2079-0619-2019-22-2-49-61

10. **Jolliffe I.T.** Principal component analysis. New York: Springer, 2002. 488 p. DOI: 10.1007/b98835

11. **Xiaomei Ni**. Civil aviation safety evaluation based on deep belief network and principal component analysis / N. Xiaomei, W. Huawei, C. Changchang, H. Jiyu, S. Zhongdong // Safety Science. 2019. Vol. 112. P. 90–95. DOI: 10.1016/j.ssci.2018.10.012

12. **Sharov V.D.** Methodology for estimating the safety and quality of the aviation service provider activities using the principal component analysis / V.D. Sharov, V.V. Vorob'ev, N.I. Nikolaikin, V.L. Kuznetsov, S.A. Tolstykh // Russian Aeronaut. 2020. Vol. 63, no. 4. P. 575–585. DOI: 10.3103/S1068799820040030

13. **Боровиков В.П.** STATISTICA. Искусство анализа данных на компьютере. Для профессионалов. 2-е изд. (+CD). СПб: Питер, 2003. 700 с.

14. **Glendon A.I., Clarke S.G., Mckenna E.F.** Human safety and risk management. 2nd ed. Florida: CRC Press, 2006. 528 p. DOI: 10.1201/9781420004687

15. **Куклев Е.А.** Автоматизированная система мониторинга и контроля полетов воздушных судов по критерию приемлемого риска на основе управления базами данных // Научный Вестник МГТУ ГА. 2007. Т. 122. С. 37–44.

16. **Wang Y.C.** Prediction of engine failure time using principal component analyses, categorical regression tree and back propagation network [Электронный ресурс]. Journal of Ambient Intelligence and Humanized Computing. 2018. DOI: 10.1007/s12652-018-0997-7 (дата обращения: 03.03.2021).

17. **Voicu I.** Risk management with bowtie diagrams / I. Voicu, F.V. Panaitescu, M. Panaitescu, L.G. Dumitrescu, M. Turof [Электронный ресурс] // IOP Conference Series: Materials Science and Engineering. 2018. Vol. 400, iss. 8. 6 p. DOI: 10.1088/1757-899X/400/8/082021 (дата обращения: 03.03.2021).

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