ТРАНСПОРТНЫЕ СИСТЕМЫ
2.9.1 – Транспортные и транспортно-технологические системы страны, ее регионов и городов, организация производства на транспорте;
2.9.4. – Управление процессами перевозок;
2.9.6 – Аэронавигация и эксплуатация авиационной техники;
2.9.8 – Интеллектуальные транспортные системы

УДК 347.822.4
DOI: 10.26467/2079-0619-2023-26-5-8-18

The problem of risk management for flight safety in the field of aviation fuel supply of air transportation

I.V. Beliatskii[1], V.M. Samoylenko[1], A.N. Kozlov[1]
[1]Moscow State Technical University of Civil Aviation, Moscow, Russia

Abstract: At the present stage of the development of aviation activity, there is a significant increase in aviation traffic, which in turn puts a significant burden on the supply of jet fuel to civil aviation. On average, 10.9 million tons of aviation kerosene per year are supplied to the domestic market of the country[1]. In Russia, a significant market share in the supply of aviation fuel is occupied by the leaders, among which now are Lukoil, Rosneft and Gazprom which all together are vertically integrated oil companies (VIOC). Along with the colossal volumes of production and supply of jet fuel, which include many technological operations, starting from the production stage to the direct delivery "to the wing" of the aircraft, the probability of production and supply of not only high quality, but also substandard jet fuel increases. Substandard fuel poses a rather serious threat during the operation of aviation equipment, being one of the many factors leading to failures of aviation equipment, aviation accidents and incidents, thereby reducing the level of flight safety. Oil refining companies, refueling complexes and airlines are interested in the safety of their activities, which have reliable systems and means to ensure it, but nevertheless substandard fuel takes place. One of the important reasons is the lack of a unified integrated flight safety system in terms of aviation fuel supply for air transportation, and therefore, it is necessary to search for new or implement existing adapted methods, solutions, systems and means to ensure the required level of flight safety.

Key words: flight safety, risk, risk management, adapted flight safety management system, aviation fuel, vertically integrated oil companies, refueling complexes, aircraft.

For citation: Beliatskii, I.V., Samoylenko, V.M., Kozlov, A.N. (2023). The problem of risk management for flight safety in the field of aviation fuel supply of air transportation. Civil Aviation High Technologies, vol. 26, no. 5, pp. 8–18. DOI: 10.26467/2079-0619-2023-26-5-8-18

Проблема управления рисками для безопасности полетов в области авиатопливообеспечения воздушных перевозок

И.В. Беляцкий[1], В.М. Самойленко[1], А.Н. Козлов[1]
[1] Московский государственный технический университет гражданской авиации, г. Москва, Российская Федерация

Аннотация: На современном этапе развития авиационной деятельности наблюдается значительный рост авиационных воздушных перевозок, что в свою очередь дает существенную нагрузку на снабжение гражданской авиации реактивным

[1] Manufacture of refined petroleum products. Basic criteria. The Ministry of Energy of the Russian Federation official website. Available at: https://minenergo.gov.ru/node/1213 (accessed: 05.09.2022). (in Russian)

топливом. В среднем на внутренний рынок страны поставляется около 10,9 млн тонн авиационного керосина в год[1]. В Российской Федерации значительную долю рынка в поставках авиационного топлива занимают вертикально интегрированные нефтяные компании (ВИНК), лидерами среди которых в настоящий момент являются «Лукойл», «Роснефть» и «Газпром». Наряду с колоссальными объемами производства и поставок авиационного топлива, включающих в себя множество технологических операций, начиная с этапа производства до непосредственной выдачи «в крыло» воздушного судна, повышается вероятность производства и поставок не только качественного, но и некондиционного авиационного топлива. Некондиционное топливо представляет достаточно серьезную угрозу в ходе эксплуатации воздушных судов, являясь одним из множества факторов, приводящих к отказам авиационной техники, авиационным происшествиям и инцидентам, снижая тем самым уровень безопасности полетов. В вопросах безопасности своей деятельности заинтересованы нефтеперерабатывающие компании, топливозаправочные комплексы и авиакомпании, которые имеют надежные системы и средства ее обеспечения, но тем не менее некондиционное топливо имеет место. Одной из важных причин является отсутствие единой комплексной системы обеспечения безопасности полетов в части авиатопливообеспечения воздушных перевозок, в связи с чем необходим поиск новых или внедрение существующих адаптированных методик, решений, систем и средств обеспечения требуемого уровня безопасности полетов.

Ключевые слова: безопасность полетов, риск, управление риском, адаптированная система управления безопасностью полетов, авиационное топливо, вертикально интегрированные нефтяные компании, топливозаправочные комплексы, воздушное судно.

Для цитирования: Беляцкий И.В., Самойленко В.М., Козлов А.Н. Проблема управления рисками для безопасности полетов в области авиатопливообеспечения воздушных перевозок // Научный Вестник МГТУ ГА. 2023. Т. 26, № 5. С. 8–18. DOI: 10.26467/2079-0619-2023-26-5-8-18

Introduction

Aviation fuel is one of the most important links in a key chain of aircraft preparation for the flight. Expenses of aircraft operators for aviation fuel are no less than 30 percent of total cost during aircraft operation. Daily aviation fuel consumption in Russia is about 15–16 thousand of tons.[2] Provision of high quality aviation fuel is a priority task for all responsible organizations, involved in the following services delivery.

Aviation fuel supply of air transportation is a complicated system, which includes the following stages:

1) manufacturing at oil refining factories;
2) quality control;
3) filtration;
4) transportation:
   - by conduit pipe;
   - by auto transport;
   - by maritime transport;
   - by railroad transport;
5) reception to fueling company refinery;
6) storage;
7) preparation for delivery;
8) delivery to an aircraft.

There is a multitude of dangerous factors [1] at all the above-mentioned stages. For instance: agent usage, selection of tests, tankage clearing procedures inobservance; violation of laboratory procedure calibration procedure; non-control of conduit pipe, mooring fitting service and conduit pipe flushing, the untimely filter element renewal; the use of damaged filter elements in working environment, the use of non-specialized loading and off-loading sleeves/hosepipes; the use of reservoirs with damaged inner coverage; sedimentation and drainage procedures inobservance before aviation fuel dispatch; violation of fuel preparation procedures; violation of aviation fuel filling procedures; safety-first procedures inobservance by responsible staff, etc.

Dangerous factors may have singular manifestations at different parts of aviation fuel manufacturing and supply chain, forming a combination of factors, leading to substandard aviation fuel entry into a market and following aviation incidents.

According to flight safety analysis data[3,4] from 2009 to 2021 there is a tendency to high level of

[2] Airports of Siberia and Far East lack kerosene-type jet fuel [Electronic resource] // Prima Media.ru. Available at: https://primamedia.ru/news/139651/ (accessed: 10.09.2022). (in Russian)

[3] The FAAT Rosaviatsiya archives of aviation and work-related incidents. Available at: https://archive.aviaregistr.ru/ (accessed: 10.09.2022). (in Russian)

[4] The automated aircraft flight safety system of the Russian Federation. The Federal Agency for Air Transport (Rosaviatsiya). P. 62. Available at: https://favt.gov.ru/dejatelnost-is/?id=3967 (accessed: 10.09.2022). (in Russian)

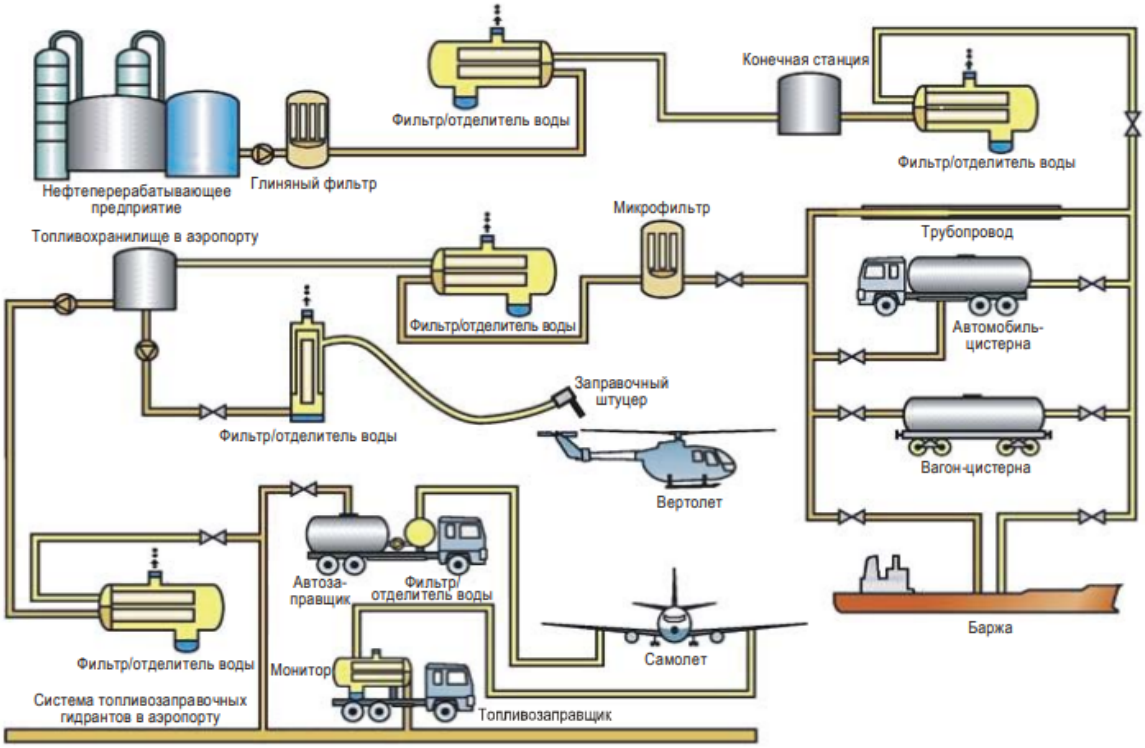

Fig. 1. Scheme for the supply and distribution chain from refinery to aircraft[5]:
нефтеперерабатывающее предприятие – oil refinery; глиняный фильтр – clay filter; фильтр / отделитель воды – water filter/separator; конечная станция – terminal; топливохранилище в аэропорту – airport fuel storage; микрофильтр – microfilter; заправочный штуцер – filter connector; вертолет – helicopter; трубопровод – conduit pipe; автомобильная цистерна – motor tank track; вагон-цистерна – car tank track; автозаправщик – tanker; монитор – monitor; топливозаправщик – fuel tanker; самолет – plane; баржа – barge; система топливозаправочных гидрантов в аэропорту – airport fueling fireplug system

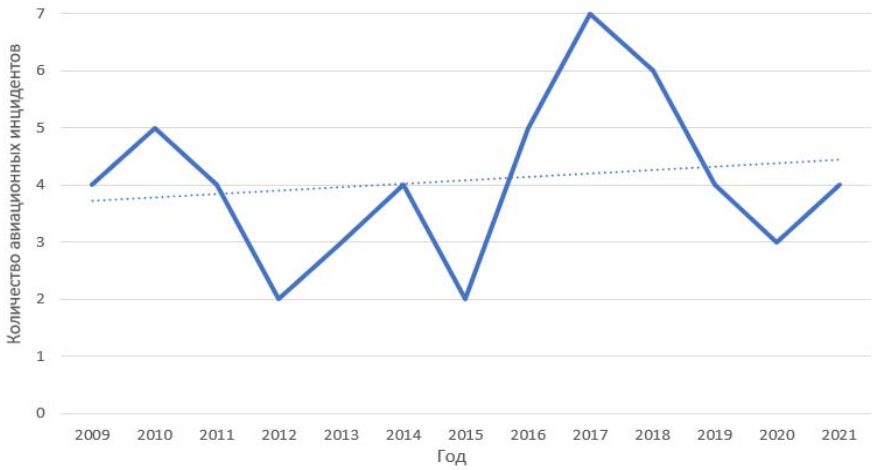

Fig. 2. The total number of aviation incidents related to aircraft fuel supply in the Russian Federation from 2009 to 2021

aircraft incidents not only due to technical failures and flight control procedures violation, but also because of substandard fuel provision.

[5] Doc. 9977 AN/489. (2012). Manual on civil aviation jet fuel supply. ICAO, 46 p.

Fig. 3. The general principle of flight safety risk management of aviation fuel supply companies for air transportation

The main part of aviation events is related to mechanical solids in fuel and water contamination, along with violation of aviation fuel filling procedures and safety-first inobservance by the staff in charge. As an aircraft has a broad destination network, it is difficult enough, and frequently impossible at all to detect an airport where the substandard fuel is used, which, in its turn, subsequently affects airworthiness and flight safety. According to FAR-10[6], this is exactly an operator who is fully responsible for flight safety, not a fueling company. The reason is that the following companies just do not have a flight safety risk management system (thereafter FSRMS) in terms of services being provided. Airport operator, who develops and operates FSRMS, including all kinds of airport business by service providers [2, 3], is obliged to possess a FSRMS, according to FAR-441[7] and the 642 Government Resolution[8].

[6] The Order of the Ministry of Transport of the Russian Federation dated 12.01.2022 № 10 “On the establishment of Federal Aviation Rules "The requirements to the entities, individual undertakers operating commercial air transportation" The Federal Agency for Air Transport (Rosaviatsiya). P. 62. Available at: https://favt.gov.ru/dokumenty-federalnyepravila/?id=2874 (accessed: 10.09.2022).

[7] The Order of the Ministry of Transport of the Russian Federation dated 02.11.2022 № 441 “On the establishment of Federal Aviation Rules "The requirements to the fixed-base operators of civil aviation airports". GARANT.RU. The information and legislation resource. P. 14. Available at: https://www.garant.ru/products/ipo/prime/doc/405745917/ (accessed: 10.09.2022). (in Russian)

[8] The Order of the Government of the Russian Federation dated 12.04.2022 № 642. “For flight safety management systems development and operation rules approval, along with data on dangerous factors and risk for civil aviation aircraft flight safety collection and analysis, data storage and exchange according to ICAO international standards and for recognition of some Federal Government acts invalid” (the act has not entered into force). GARANT.RU. Informational and legal web portal. 7 p. Available at: https://www.garant.ru/products/ipo/prime/doc/404379316/ (accessed: 10.09.2022). (in Russian)

Fig. 4. Classification of dangerous factors

Research method and methodology

FSRMS of aviation fuel service provider development and implementation is an extensive challenge [4, 5] in circumstances of market relations and flight safety provision.

It is necessary either to develop new decisions and methods or adjust the existing ones in order to provide flight safety in terms of services provided by manufacturers, suppliers, fueling companies and aviation fuel quality control organizations.

FSRMS of corporates, providing aviation fuel supply services, is developed according to the general risk management principle[9] [6–8].

Civil aviation flight safety analysis in the last few years indicates the problem of aviation fuel supply and necessity of risk management in these terms.

The first stage of risk management starts with dangerous factors revealing and ranging. This step is technically complicated, as it includes the total of aviation fuel supply organizations: manufacturers, POL suppliers, fueling and POL quality control organizations.

The essence of the second stage is dangerous factors action risk assessment. Risk assessment has always been the most complicated part of aviation risk management process due to subjectiveness of consequences severity at danger manifestation and lack of information [9–11].

At the following stage of aviation fuel supply corporates work it is necessary to choose one or more of flight safety risk management methods and adjust them for the industry in question.

It is advisable to use and adjust methods, which are implemented widely in airline companies which have experience of use, wide statistics and practice of integrated methods – “ICAO Risk Assesment Matrix” [12] and “Bow-tie method” [13].

Bow-tie is a simple and efficient method, based on potential risk analysis and schematical description. Left part of the Bow-tie is a reason, the knot itself is an event, the right part symbolizes a consequence. The Bow-tie method is unique for the opportunity of understanding the reasons of materialized risk, which, in other words, have already taken place. It is also possible to develop

[9] GOST R 57239-2016 Air transport (2021). Safety management of aviation activity. Data base. Aviation infrastructure risks of airport operation. Moscow: Standartinform, 24 p. (in Russian)

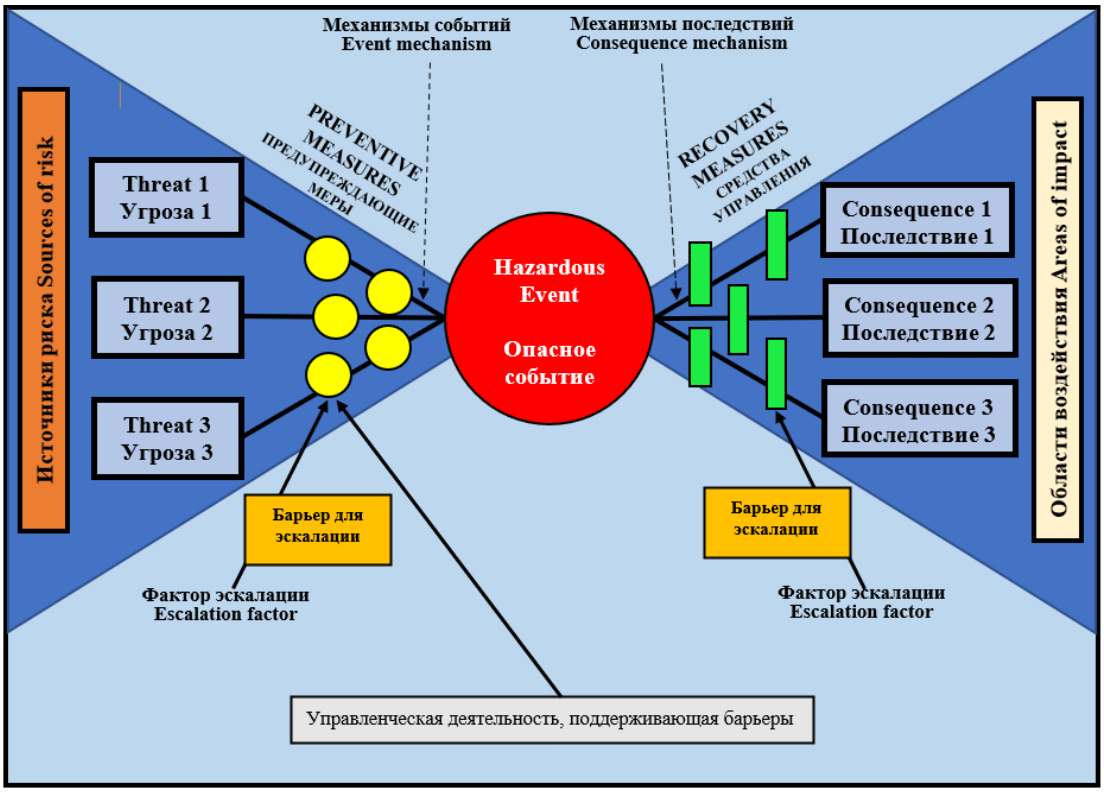

Fig. 5. Bow-tie risk management method[10]

Table 1

The example of using the Bow-tie method

THREAT	Recovery measures	Hazardous event	Control measures	Consequence
The untimely fuel tanks clearing	Inspection of procedure fulfillment by technical control department staff members. Company staff periodical training and qualification assessment	EICAS MESSAGE "ENGINE FUEL FILTER R" in this case the following message indicates right engine fuel filter clogging	Normative and technical documentation requirements for aviation fuel quality, fueling and storage procedures	Rejected take-off/incident
End lug pollution during pressure fill				Aircraft malfunction
The untimely checkout of means of cleaning and water trapping system at fuel filling point				Airline company scheduled flight frequency deterioration

approaches and reveal risk management factors basing on results of the research [14].

Research stages by Bow-tie method:

- Risk revelation in order to form Bow-tie diagram foundation.
- Event reasons determination considering risk sources.
- Complex analysis of risk reason potential development before the moment of unwanted event.
- Risk linking with the main reasons.
- Including the reasons leading to risk probability increase into the diagram.

[10] GOST R 58771-2019. (2020). Risk management. Risk assessment technologies Moscow: Standartinform, 78 p. (in Russian)

Table 2

ICAO Risk Assessment Matrix

The probability of risk in the framework of aviation fuel supply of aircraft		Risk severity				
		Catastrophic A	**Hazardous B**	**Major C**	**Minor D**	**Negligible E**
5	Frequent	5A	5B	5C	5D	5E
4	Occasional	4A	4B	4C	4D	4E
3	Remote	3A	3B	3C	3D	3E
2	Improbable	2A	2B	2C	2D	2E
1	Extremely improbable	1A	1B	1C	1D	1E
Risk levels		Inappropriate risk level				
		Permissible risk level				
		Appropriate risk level				

- Planning of defense measures for risk prevention.
- Risk consequences listing.
- Development of correction measures and solutions for their mitigation.

There is an example of the method implementation in case of the event EICAS MESSAGE BOEING 777 “ENGINE FUEL FILTER R” (in this case the following message signs about right engine fuel filter clogging).

Risk assessment method with ICAO risk assessment matrix is an assessment of dangerous manifestation probability and severity of probable events, linked with revealed dangerous factors [12].

It is necessary to match the level of ICAO matrix complexity with needs and production tasks of the certain organization. Besides that, it is necessary to notice that both qualitative and quantitative criteria can be used in organizations (up to 15 different values).

The scale of dangerous factors manifestation probability is determined by organizations themselves or by their responsible persons, possessing authority in terms of risk management, acting as risk owners.

Risk factors probability for flight safety is determined as a probability of hazardous event or result manifestation or repetition.

It is worth noticing, that initial data for dangerous factor manifestation probability derivation is an analysis of similar dangerous factors, appeared within the risk monitoring period (week, month, year).

Tables of dangerous factor probability and severity assessment are used for dangerous factor analysis.

Let us consider such a dangerous factor, revealed during auditing aviation fuel supply corporate auditing, as water and mechanical contamination in the airfield fuel storage tank. According to the expert opinion of risk owners, let us assume the following as manifestation of the given dangerous factor:

- rejected takeoff/incident;
- clogging of the aircraft fuel filter;
- providing of services, not meeting safety requirements;
- claims of the customer;
- fuel tanker withdrawal for a certain period of time.

Every dangerous factor manifestation is an alleged event, for which it is necessary to determine its probability and severity.

Severity assessment should consider all the possible consequences of the dangerous factor, based on the worst alleged situation. For instance, the probability of manifestation of a such

dangerous event as a rejected takeoff – an incident due to dangerous factor affection, revealed during auditing, is determined as remote by risk owner, along with "major" severity. Risk owner supposes this basing on large data package analysis results, knowledge and experience in terms of expert assessment, along with tables of risk severity[11] and probability for flight safety, made basing on them.

Let us determine risk level with ICAO matrix[12] after dangerous event manifestation probability due to dangerous factor affection and consequences severity having been outlined. There is a risk level 3C in the following case. The obtained value indicates the permissible risk level.

The essence of the third and the fourth stages of risk assessment is taking correction measures for decreasing probability of dangerous event manifestation and its consequences, along with their control and monitoring in terms of aviation fuel supply corporates [15].

Conclusion

Nowadays FSRMS implementation in aviation fuel supply corporates is a key challenge. Risks are managed by using the existing qualitative methods in order to operate FSRMS.

Efficiency of the following methods use is determined by collection of reliable data on dangerous factors manifestation at aviation fuel supply corporates work, correction and preventive measures development and timely decisions made by authorities.

Each of the methods described has its advantages and disadvantages. The "Bow-tie" allows us to assess the risks which have already taken place, and the matrix method allows us to predict the risks. However, both methods cannot be used for any quantitative calculations as the following methods do not reflect the total of reasons, which can occur simultaneously and cause consequences. It is also worth noticing, that risk matrix is only the instrument for qualitative risk assessment [16].

The simplicity of these methods application allows to implement them at initial stages of flight safety provision system at aviation fuel supply corporates, which, in its turn, increases the charges and time for its formation. Implementation of qualitative methods is also possible along with risk management quantitative approaches in further work. The integrated use of this methods allows to gain the best, practically significant and reliable result.

[11] Doc. 9859 AN/474. (2018). Safety Management Manual. 4rd ed. ICAO, 218 p.

[12] Doc. 9859 AN/474. (2018). Safety Management Manual. 4rd ed. ICAO, 218 p.

References

1. Sukhikh, N.N., Dalinger, Y.M., Kudryakov, S.A., Horoshavtcev, Y.E., Matciyevskiy, Y.M. (2017). Risk factors management for flight safety improvement purposes. *Revista Espacios*, vol. 38, no. 33, p. 24.

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

3. Zubkov, B.V., Fourar, H.E. (2017). Flight safety management problems and evaluation of flight safety level of an aviation enterprise. *Civil Aviation High Technologies*. vol. 20, no. 5, pp. 145–151. DOI: 10.26467/2079-0619-2017-20-5-145-151 (in Russian)

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

5. Sharov, V.D., Vorob'ev, V.V., Nikolaikin, N.I., Kuznetsov, V.L., Tolstykh, S.A. (2020). Methodology for estimating the safety and quality of the aviation service provider activities using the principal component analysis. *Russian Aeronautics*, vol. 63, pp. 575–585. DOI: 10.3103/S1068799820040030

6. Palamarchuk, G.I., Liberman, P.Yu. (2022). Risk management imperatives in aviation activity. *Proceedings of Petersburg Transport University*, vol. 19, no. 3, pp. 489–497.

DOI: 10.20295/1815-588X-2022-3-489-497 (in Russian)

7. Muller, R., Wittmer, A., Drax, C. (Eds.). (2014). Aviation risk and safety management. Methods and applications in aviation organizations. Springer International Publishing Switzerland, 216 p. DOI: 10.1007/978-3-319-02780-7

8. Selyukov, V.K. (2008). Risk management of the organization: teaching aid. Moscow: MGTU im. N.E. Baumana, 189 p. (in Russian)

9. Belenkov, V.G., Volkov, M.V., Godikov, D.A., Kan, A.V. (2022). The methodology of proactive aviation safety management and the formation of reliable predictive assessments of the level of flight safety. *Highly Available Systems*, vol. 18, no. 1, pp. 39–46. DOI: 10.18127/j20729472-202201-04 (in Russian)

10. Honcharenko, Y., Martyniuk, O., Open'ko, P., Radko, O. (2020). The method of proactive risk assessment for flight safety based on the rate of dangerous events. *Advances in Military Technology*, vol. 15, no. 2, pp. 365–377. DOI: 10.3849/aimt.01424

11. Yeun, R., Bates, P., Murray, P. (2014). Aviation safety management systems. *World Review of Intermodal Transportation Research*, vol. 5, no. 2, pp. 168–196. DOI: 10.1504/WRITR.2014.067234

12. Mostafa, A. (2020). Safety and risk assessment of civil aircraft during operation. China, Intechopen, 212 p. DOI: 10.5772/ intechopen.93326

13. Gareth, B. (2007). Practical HSE risk management – an introduction to the Bow-tie Method. *In: International Conference for Achieving Health & Safety Best Practice in Construction*. Dubai, UAE, 26–27 February, Risktec Solutions Ltd., 30 p. Available at: https://maddenmaritime.files.wordpress.com/2013/01/introduction-to-bow-tie-method-dubai.pdf (accessed: 27.12.2022).

14. Kartvelishvili, V.M., Sviridova, O.A. (2017). Risk management. Methods of risk assessment: Tutorial. Moscow: FGBOU VO "REU im. G.V. Plekhanova", 120 p. (in Russian)

15. Li, Z., Xu, H., Xue, Y., Pei, B. (2018). Construction method of flight safety manipulation space based on risk prediction. *Journal of Beijing University of Aeronautics and Astronautics*, vol. 44, no. 9, pp. 1839–1849. DOI: 10.13700/j.bh.1001-5965.2017.0686

16. Zubkov, B.V., Sharov, V.D. (2010). Theory and practice of determining risks in aviation enterprises during the development of a safety management system: Monography. Moscow: MGTU GA, 196 p. (in Russian)

Список литературы

1. Sukhikh N.N. Risk factors management for flight safety improvement purposes / N.N. Sukhikh, Y.M. Dalinger, S.A. Kudryakov, Y.E. Horoshavtcev, Y.M. Matciyevskiy // Revista Espacios. 2017. Vol. 38, no. 33. P. 24.

2. Лушкин А.М. Типовая система управления безопасностью полетов эксплуатанта воздушных судов России // Научный Вестник МГТУ ГА. 2017. Т. 20, № 1. С. 8–16.

3. Зубков Б.В., Фурар Х.Э. Проблемы системы управления безопасностью полетов и определения уровня безопасности полетов авиационного предприятия // Научный Вестник МГТУ ГА. 2017. Т. 20, № 5. С. 145–151. DOI: 10.26467/2079-0619-2017-20-5-145-151

4. 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

5. 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 Aeronautics. 2020. Vol. 63. Pp. 575–585. DOI: 10.3103/S1068799820040030

6. Паламарчук Г.И., Либерман П.Ю. Императивы управления рисками в авиационной деятельности // Известия Петербургского университета путей сообщения. 2022. Т. 19, № 3. С. 489–497. DOI: 10.20295/1815-588X-2022-3-489-497

7. Aviation risk and safety management. Methods and applications in aviation organizations / Под ред. R. Muller, A. Wittmer, C. Drax. Switzerland: Springer, 2014. 216 p. DOI: 10.1007/978-3-319-02780-7

8. Селюков В.К. Риск-менеджмент организации: учеб.-метод. пособие. М.: МГТУ им. Н.Э. Баумана, 2008. 189 с.

9. Беленков В.Г. Методика проактивного управления безопасностью авиационной деятельности и формирования достоверных прогностических оценок уровня безопасности полетов / В.Г. Беленков, М.В. Волков, Д.А. Годиков, А.В. Кан // Системы высокой доступности. 2022. Т. 18, № 1. С. 39−46. DOI: 10.18127/j20729472-202201-04

10. Honcharenko Y. The method of proactive risk assessment for flight safety based on the rate of dangerous events / Y. Honcharenko, O. Martyniuk, P. Open'ko, O. Radko // Advances in Military Technology. 2020. Vol. 15, no. 2. Pp. 365–377. DOI: 10.3849/aimt.01424

11. Yeun R., Bates P., Murray P. Aviation safety management systems // World Review of Intermodal Transportation Research. 2014. Vol. 5, no. 2. Pp. 168–196. DOI: 10.1504/WRITR.2014.067234

12. Mostafa A. Safety and risk assessment of civil aircraft during operation. China: Intechopen, 2020. 212 p. DOI: 10.5772/intechopen.93326

13. Gareth B. Practical HSE risk management – an introduction to the Bow-tie Method [Электронный ресурс] // International Conference for Achieving Health & Safety Best Practice in Construction. Dubai, UAE, 26–27 February 2007. Risktec Solutions Ltd., 30 p. URL: https://maddenmaritime.files.wordpress.com/2013/01/introduction-to-bow-tie-method-dubai.pdf (дата обращения: 27.12.2022).

14. Картвелишвили В.М., Свиридова О.А. Риск-менеджмент. Методы оценки риска: учеб. пособие. М.: ФГБОУ ВО «РЭУ им. Г.В. Плеханова», 2017. 120 с.

15. Li Z. Construction method of flight safety manipulation space based on risk prediction / Z. Li, H. Xu, Y. Xue, B. Pei // Journal of Beijing University of Aeronautics and Astronautics. 2018. Vol. 44, no. 9. Pp. 1839–1849. DOI: 10.13700/j.bh.1001-5965.2017.0686

16. Зубков Б.В., Шаров В.Д. Теория и практика определения рисков в авиапредприятиях при разработке системы управления безопасностью полетов: монография. М.: МГТУ ГА, 2010. 196 с.

Information about the authors

Ildar V. Beliatskii, Postgraduate Student of the Aviation Fuel Supply and Aircraft Repair Chair, Moscow State Technical University of Civil Aviation, belyackiii@bk.ru.

Vasily M. Samoylenko, Doctor of Technical Sciences, Professor, The Head of the Aviation Fuel Supply and Aircraft Repair Chair, Moscow State Technical University of Civil Aviation, v.samoilenko@mstuca.aero.

Alexander N. Kozlov, Candidate of Technical Sciences, Associate Professor of Aviation Fuel Supply and Aircraft Repair Chair, Moscow State Technical University of Civil Aviation, an.kozlov@mstuca.aero.

Сведения об авторах

Беляцкий Ильдар Васильевич, аспирант кафедры авиатопливообеспечения и ремонта летательных аппаратов МГТУ ГА, belyackiii@bk.ru.

Самойленко Василий Михайлович, доктор технических наук, профессор, заведующий кафедрой авиатопливообеспечения и ремонта летательных аппаратов МГТУ ГА, v.samoilenko@mstuca.aero.

Козлов Александр Николаевич, кандидат технических наук, доцент кафедры авиатопливообеспечения и ремонта летательных аппаратов МГТУ ГА, an.kozlov@mstuca.aero.

Поступила в редакцию	14.02.2023	Received	14.02.2023
Одобрена после рецензирования	04.03.2023	Approved after reviewing	04.03.2023
Принята в печать	21.09.2023	Accepted for publication	21.09.2023