

Ensuring the ornithological safety of aircraft flights in conditions of deep uncertainty

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Abstract: *Analysed the influence of the threat of an aircraft collision with birds as the most important factor in flight safety (bird strike problem). An analytical review of aviation accidents with birds for the period 2010-2022 was carried out. The problem of ensuring ornithological flight safety considered as decision-making under conditions of uncertainty problem. Existing approaches to assessing the level of ornithological danger in aviation and decision-making are discussed. A scenario approach to reducing the risk of bird strike danger as a task of decisions making in conditions of uncertainty is proposed*

Keywords: *BIRD STRIKES, BIRD INGESTION, BIRD HIT, BIRD AIRCRAFT STRIKE HAZARD, AVIATION EMERGENCIES, FLIGHT SAFETY, ORNITHOLOGICAL DANGER, PARTIAL UNCERTAINTY, DEEP UNCERTAINTY, RISKS.*

1. Introduction

The problem of aircraft collisions with birds (bird strike) is updated with the growing trends in the number of air transportation in the world. According to the International Civil Aviation Organization (ICAO), over seven years, 97,751 aircraft collisions with animals were recorded in 105 countries around the world. In approximately half of the cases (56,093 incidents), damage to the aircraft of various types is reported after an encounter with animals [1]. According to some estimates, the annual damage from aircraft collisions with birds is about 610 ml. \$ [2]. At the same time, the most dangerous are birds getting into an aircraft engine, in which the likelihood of engine failure can lead to catastrophic consequences. According to ICAO, the engine accounts for about 20% of all bird hits, but only in rare cases such bird strikes can completely destroy the engine [1].

According to data from the Federal Air Transport Agency of the Russian Federation (Rosaviatsiya), in 2022, 941 reports of threatened aircraft collisions with birds were registered, including 85 of them considered as aviation accident [3].

ICAO offers for review a number of documents on ensuring ornithological safety [1, 4-5]. In Russia, the main provisions for ornithological support of flights in civil aviation are set out in the Guide to Ornithological Support of Flights in Civil Aviation (ROOP GA-89) [6]. The Russian Ministry of Transport is developing rules to combat the danger created by animals at airfields, but at present such rules have not yet entered into force [7]. In the USA, the Federal Civil Aviation Administration (FAA) has also developed relevant documents in the field of ensuring ornithological safety [8-9]. It should also be noted that various international organizations (World BirdStrike Association, International Birdstrike Committee, etc.) that study ornithological safety of flights, publish relevant instructions and practical advice, which are advisory in nature [10-12].

Considering statistical data for 2022 using the example of the Russian Federation, it can be noted that in 85 cases the incidents had an impact on flight safety, but did not lead to aviation accidents (i.e. situations that could lead to loss of life, significant material damage and other serious consequences) [3].

In Russia, a system of voluntary flight safety reports is being distributed and maintained, however, due to the voluntary nature of sending reports, it is quite difficult to talk about the completeness and reliability of such data. However, since 2015, the start of voluntary reporting can be traced according to statistics (Fig. 1).

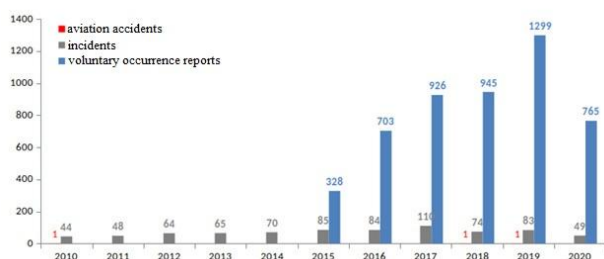


Fig. 1. Bird strike statistics in Russia for the period 2010-20

The relevance of the research in this direction is determined by the fact that the development of new models and methods in assessing the risk of bird collisions with air transport will make it more likely to calculate the likelihood of catastrophic consequences by using the most optimal methods and technical devices to counter the expected threat, which as a result will be able to make aviation transportation even safer for passengers, prevent significant damage, and in some cases avoid unnecessary costs for the airline on ornithological safety measures, if the risk of such dangerous situations is not too high.

2. Problem discussion

Scientists from several disciplines are involved in the issues of bird strikes - both specialists in biology and zoology, scientists in the field of flight safety: O.L. Silaeva, M.V. Kholodova, T.V. Sviridova, S.A. Bukreev, V.A. Yudkin, Grabovsky M.A., A.N. Varaksin, A.I. Rogachev, A.M. Lebedev et al. [17-19]. Scientists also analysed and assessed the risks of bird collisions with aircraft - A.G. Guziy, L.N. Elisov, G. van Es, HH Smit, Isabel C. Metz, Joost Ellerbroek, Thorsten Mühlhausen, Dirk Kügler, Jacco M. Hoekstra [20-23].

Analysing the bird strike problem and existing works about ornithological safety, we can identify the following main problems of ornithological security in aviation:

1. Assessment of ornithological danger solely on the basis of statistical information, the completeness and reliability of which is questionable.
2. Lack of sufficient up-to-date data on the ornithological situation in a number of regions and areas.
3. Lack of unified developed methods and specific instructions for ensuring ornithological flight safety (established by ICAO, states instr., etc.). International and main government documents regulating actions to ensure ornithological safety of flights formulate requirements for assessing the intensity of bird flights and contain the concepts of «large concentrations of birds», «mass flights», «difficult ornithological conditions» [19, 25-26]. Scientists also note, quote - «At the same time, there are no explanations provided anywhere on what method should be used to assess the intensity of flights, there are no clear quantitative criteria for the size of bird concentrations, and the complexity of the situation is recommended to be assessed only by the number of documented incidents with birds» [19].

The listed problems in practice lead to the formation of the following extremes in ensuring ornithological flight safety: a) insufficient attention to ornithological flight safety (implies insufficient funding for this area or negligence in ornithological work in general), which can increase the risk of aircraft collision with birds in close proximity to airfield, in the area of its conditional responsibility; b) excessive attention to ornithological safety (implies excessive funding) reduces the economic efficiency of the airline, but does not reduce risks.

As common solutions for assessing the risk of bird threat at an airport, various threat assessment methods are currently used:

- 1) Method for assessing ornithological danger by calculating the probability of an aircraft collision with birds [15].

$$C = 1,5 \times 10^{-6} \times (B \times M_b) \quad (1)$$

,where B – is the number of birds per km^2 ; M_b – average weight of one bird, kg.

The above calculation can be used to assess the probability of a catastrophic collision as a universal formula, while the ornithological service of the airport, as a rule, should have up-to-date information about the presence of birds and their species, numbers, which will allow establishing more accurate digital values for the probability of a threat.

2) A method for quantitative assessment of the risk caused by aircraft collisions with birds according to the works of A.G. Guziy, A.P. Kostin [22, 23]. The value of the conditional probability of an incident as a result of an aircraft collision with a bird ($P_{I.col.}$) is proposed to be determined from the annual statistics of bird strikes of the country for which the calculation is made, using the formula:

$$\hat{P}_{I.col.} = \frac{n_I}{n_{col.}} \quad (2)$$

,where $P_{I.col.}$ – conditional probability of an incident when an aircraft collides with a bird; n_I and – number of incidents; $n_{col.}$ – number of collisions.

To further assess the level of risk, it is proposed to use the 5x5 risk index matrix recommended by ICAO and the ratio of the probability of events per 100 thousand flights [24]. However, as aviation scientists note, the ICAO risk matrix must be used with caution [21].

The considered methods allow us to assess the risk of ornithological threats and are based on statistical data. The use of statistics can be justified if sufficient statistics are available for specific areas and runway locations, and can also be of great importance when creating new airports. But, only if these statistics are relevant and based on real events, and not created for fictitious and/or formal reporting indicators.

3. Models and methods of research

Solving the problem of decision-making in the field of ensuring ornithological flight safety is complicated by the lack of accurate data to be able to calculate the probabilities of certain events.

Let us imagine the problem of ensuring ornithological flight safety as a task in a field of partial and deep uncertainty (Fig. 2):

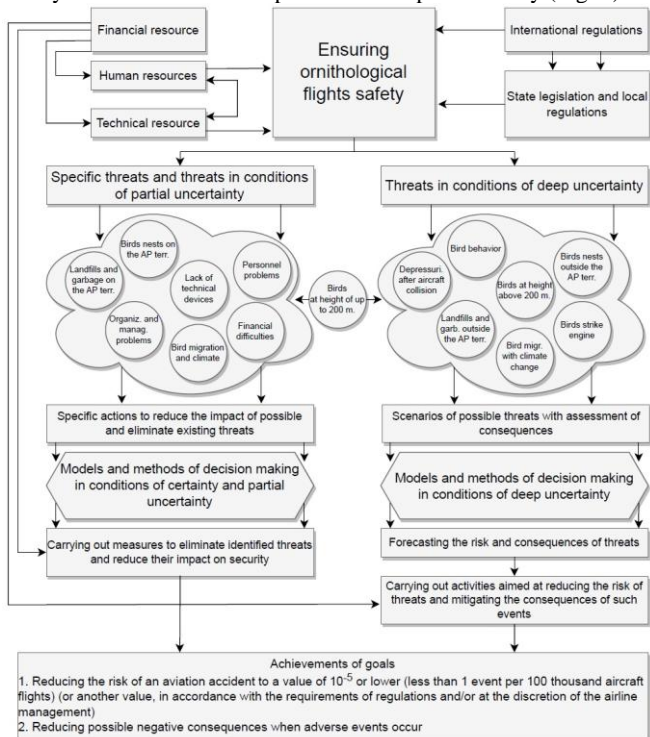


Fig. 2. The author's conceptual scheme for studying the problem of ensuring ornithological flight safety as a task in a field of partial and deep uncertainty

Based on the constructed concept, it can be noted that a number of very specific problems in the field of partial uncertainty can be solved with classical tools, including the mathematical apparatus, existing probabilistic models, among which are quite common: the Wald criterion, maximax, pessimism, Savage, Hurwitz, tools of the theory of expected utility J. von Neumann and O. Morgenstern, prospect theory by Kahneman and Tversky and others [27-29].

Solving problems in a field of deep uncertainty requires the use of special tools. Most famous of them are: Robust Decision Making (RDM), Multi-Objective Robust Decision Making (MORDM), Dynamic Adaptive Policy Pathways (DAPP), Info-gap (IG) decision theory, Engineering Options Analysis (EOA), Decision Scaling (DS), Adaptation Tipping Point (ATP), Many-Objective Robust Optimization (MORO) [30]. When considering existing methods of decision-making under conditions of deep uncertainty, you should pay attention to a scenario tool that helps create adaptive plans - Dynamic Adaptive Planning (DAP).

As a rule, DAP is carried out according to a certain algorithm, but may not be limited to it [30, 31]. An example of a dynamic adaptive planning scheme is shown below (Fig. 3) [30].

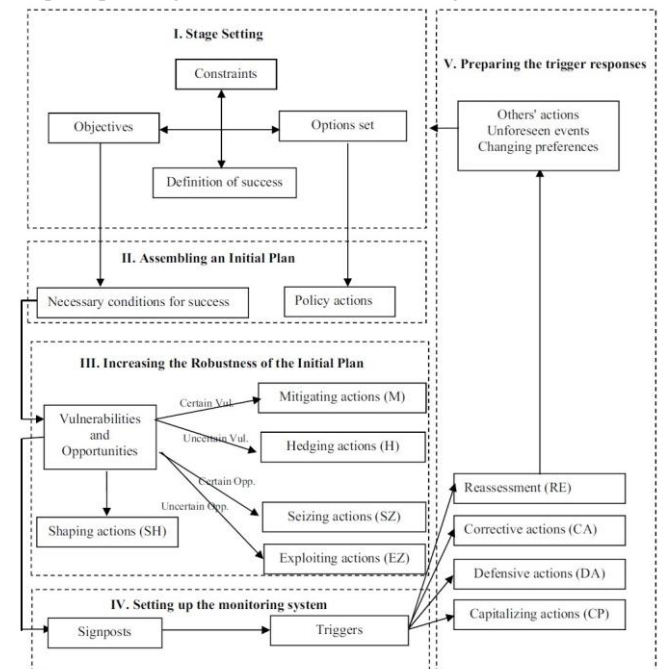


Fig. 3. Typical dynamic adaptive planning scheme. DAP stages [30]

The DAP process consists of five sequential steps. In the event of the occurrence of certain significant events (usually identified at stages 4-5), the plan becomes cyclical in nature - it can be re-evaluated, changed and supplemented. The planning process is a fairly detailed description of all processes. Within the limited scope of the article, we will consider the main and characteristic features of the scenario approach to ensure ornithological flight safety. The proposed option is theoretical, so let us assume as an example a conditional airport X in city Y and a scenario approach for solving the problem of ensuring the ornithological safety of an airline, which can be scaled to any existing airfield and real numerical values of indicators.

DAP. Stage 1. Stage Setting. Objective: ensuring ornithological safety of airport X in city Y. Constraints: 1. Organizational and managerial. 2. Weather-climatic and territorial. 3. Financial and economic (budget). Definition of success: 1. The number of voluntary reports of aircraft collisions (possible collisions) with birds at height up to 200 m does not exceed the R value. 2. The number of aircraft incidents involving birds at an height of up to 200 m does not exceed the E value. 3. The number of aircraft accidents with birds at height of up to 200 m does not exceed the U value. 4. The number of complaints from residents of

nearby areas about the measures and actions taken by the airline to reduce the number of birds does not exceed the value M . Digital values of success indicators (R , E , U , M) should be established based on possible statistical reporting data (for the previous period), and in the absence of such data, use the values also used for average statistical indicators that determine normal operation at airports with similar natural and climatic features. The setting of specific digital values is determined by the DAP monitoring system, during the operation of which it is necessary to set critical points (triggers) in signposts for taking appropriate actions within the framework of the functioning of the plan. Options set: the presence of disagreements with animal defenders regarding methods of scaring away birds and possible damage to nature (the need to ensure ornithological safety of flights without harming the ecosystem).

DAP. Stage 2. Assembling an Initial Plan.

Necessary conditions for the plan success: 1. Availability of an ornithological service in the airline (sufficient number of qualified specialists). 2. Availability of equipment and special means to ensure ornithological safety of flights. 3. Availability of necessary and sufficient funding. 4. Absence of landfills and other places of mass accumulation of birds near the airfield. 5. Organized interaction with the district administration and environmental and natural services for joint control over the ornithological threat to nearby territories.

Policy actions as external restrictive measures: lack of a sufficient selection of special technical devices for bird control due to sanctions restrictions (as well as spare parts for repair, operation and maintenance of existing systems).

DAP. Stage 3. Increasing the Robustness of the Initial Plan.

Actions taken for specific vulnerabilities and vulnerabilities under conditions of partial uncertainty: 1. The presence of a constant number of vacant positions in the number of P in the ornithological service division \rightarrow *mitigating actions* (M) \rightarrow revision of personnel policy. Increasing the efficiency of personnel bodies and services in order to ensure full staffing with relevant specialists, and, if necessary, resolving controversial issues related to working conditions and wages. 2. The presence of faulty equipment and technical means to ensure ornithological safety in the number of F units $\rightarrow M \rightarrow$ carrying out work to improve the efficiency of operation services, economic support in order to carry out prompt repairs and supply missing spare parts. 3. Organizational, managerial, personnel and financial problems of the airline $\rightarrow M \rightarrow$ Revision and optimization of costs. Solving personnel, financial and management problems. Changes in the service policy and cost of services, etc. 4. Presence of garbage dumps, places and conditions for bird nesting on the airport territory. $\rightarrow M \rightarrow$ Take measures to eliminate the landfill. Dismantling of buildings and places of possible nesting of birds, regular monitoring of the absence of nests and places of mass gathering of birds. 5. Birds at height of up to 200 m. $\rightarrow M \rightarrow$ Use of ornithological bird control means (technical, visual, repellent, etc.)

Vulnerabilities in a field of deep uncertainty and actions taken. 1. Birds at height of up to 200 m. \rightarrow *Hedging actions* (H) \rightarrow If existing means and methods of combating the ornithological threat on the runway territory cannot cope - increase attention to the problem, increase the number of means and methods of control. 2. Presence of garbage dumps, places and conditions for bird nesting outside the airport territory $\rightarrow H \rightarrow$ Organizing interaction with local authorities, neighbouring organizations and residents in order to jointly combat the ornithological threat. 3. Birds strike an aircraft engine $\rightarrow H \rightarrow$ Constant analysis of new developments in the field of protecting aircraft engines from damage by birds, consultations with aircraft manufacturers, organization of interaction between the airline and manufacturers. 4. Climate change during bird migration $\rightarrow H \rightarrow$ Monitoring climate change should be carried out with due foresight, taking into account the latest trends, and not solely based on statistics from past years. Taking climate change into account when organizing ornithological work. 5. Birds at height above 200 m. $\rightarrow H \rightarrow$ Constant analysis of

new developments in the field of protecting the aircraft hull from damage by birds, application of modern developments recommended by manufacturers. 6. Aircraft depressurization after a bird strike $\rightarrow H \rightarrow$ Increased attention to ensuring safety on board the aircraft and the supply of life support equipment. Constant monitoring of new developments in the field of life support and increasing the strength of the aircraft hull and elements. 7. Bird behavior $\rightarrow H \rightarrow$ Analysis and constant attention of the ornithological service to the latest data from ornithologists on the characteristics of bird behavior, the formation of flocks, etc.

DAP. Stage 4: Setting up the monitoring system. As a monitoring system, we can offer the option of tracking the number of voluntary messages, and, due to the fact that a significant part of the messages consists of information from the aircraft crew, who has data on the flight height (and can record it), such messages can be divided to take into account on: a) reports of collisions (threats of collision) of birds with aircraft at height of up to 200 m. b) reports of collisions (threats of collision) of birds with aircraft at height of above 200 m.

In this case, it becomes possible to evaluate the effectiveness of the undertaken scenario measures based not simply on existing statistical indicators, but using specific values for a particular airport.

As shown (Fig. 3), at stage 4 of the DAP, a number of triggers are identified to which certain actions must be linked. An increase in the numerical values of voluntary reports in the case of (a) will be a trigger - the basis for increasing the costs of associated bird control activities. It will be most effective to set specific values for triggers and actions taken (by tracking the values of the variables listed in the success indicators above), allowing you to dynamically monitor the situation and take action commensurate with the increase in threat. This is what will prevent the possibility of unnecessary costs for measures to ensure ornithological safety. Stage 5 of the DAP (Preparing the trigger responses) involves a number of actions (corrective (CA), defensive (DA), capitalizing (CP)) and measures in response to triggers; in a particular case, these may be specific actions related to staffing, the use of new or different types of ornithological control, technical devices, etc. It should also be noted that the plan reassessment (RE) item which is applied if the results of the plan do not achieve the required efficiency, which indicates that the plan needs to be revised. In the case of normal operation of the plan, stages 3-5 operate in a cyclic mode, thanks to stages 4 and 5, constant adaptation and operation of the plan occurs, which ensures its dynamism.

In the case of situation (b), we cannot talk about the possibility of preventing adverse consequences, however, in some cases, such information can be used to avoid dangerous aircraft routes in cases where there is information and sufficiently reliable forecasts about the mass migration of birds. It is also possible to include such a scenario in one of the trigger threats and provide for certain actions for this.

4. Results and conclusion

The use of risk-based approaches is a good tool for approximate assessment of possible bird situations. Meanwhile, in some cases, the assessment of such risks may be too formal in nature and is carried out solely for the purpose of compliance with various regulatory and statutory requirements of states for air carriers in terms of ensuring the necessary flight safety measures. Compliance with formal requirements is not always a practical indicator of the reliability of such measures. In addition, quite often the regulatory requirements are the bare minimum that any airline can afford; however, there are also companies that are willing to invest much larger financial resources in security, which sometimes turns out to be unnecessary.

Despite the features and practically unsolvable problems presented in the article in the field of deep uncertainty of ornithological safety, there are a number of situations when it is quite possible to reduce the risk of threat. Such opportunities should include ornithological control at low height up to 200 m, in the immediate areas of aircraft takeoff and landing, where, according to

statistical data, the probability of encounters with birds is very high. In such cases, strict adherence to bird control measures has a good chance of reducing the likelihood of such contacts. Methods for increasing the strength of aircraft hulls and elements, engine protection and other technical work in these areas deserve special attention as elements of scenario action for cases of deep uncertainty. The course of technological progress and improvement of the aircraft will undoubtedly be able to improve the safety of the aircraft over time, even when encountering flocks of large birds and at significant speeds. This is associated with certain and, as a rule, financially costly measures listed in this article, but no one doubts that security always has its own high price. The scenario analysis tool discussed in the article in conjunction with existing statistical data and risk assessment methods will allow us to take another step towards ensuring ornithological flight safety. Currently, the use of scenario analysis tools for solving problems in the aviation industry is not popular, since more well-known and common tools such as SWAT, TOWS, tree decision analyse are used. It should also be noted that there is currently no information on the use by scientists approach to issues of ornithological flight safety from the position of solving problems in a field of uncertainty, which actually predetermines the possibility of opening a new scientific foundation in this direction for the use of special tools.

Increased attention to the use of scenario analysis and planning tools that allow the development of dynamic adaptive plans aimed at ensuring ornithological safety of flights will further improve the quality of possible forecasts about aircraft encounters with birds, which can ultimately make air transport even safer.

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REFERENCES

1. ICAO Electronic Bulletin: 2008 - 2015 Wildlife Strike Analyses, 2017.
2. Meer Ahmad A.M. «Bird-strike aircraft accidents and their prevention» Asian Journal of Science and Technology, 2019, 10, (01), 9251-9257.
3. Statistics of collisions with birds and other animals. Official website of the Federal Air Transport Agency of the Russian Federation (Rosaviation). Available at: <https://favt.gov.ru/dejatelnost-bezopasnost-poletov-stolknoveniya-ptici-stat/?ysclid=lht0gjsl5z913184832> (accessed 08.15.2023).
4. ICAO Doc 9137: Airport Services Manual Part 3 - Wildlife Control and Reduction, 4th edition, 2012.
5. ICAO Annex 14 (Aerodromes).
6. Guidelines for ornithological support of flights in civil aviation (ROOP GA-89)
7. The Russian Federation Ministry of Transport will develop rules to combat the danger created by animals at airfields. Rossiyskaya Gazeta. Available at: <https://rg.ru/2023/03/15/mintrans-razrabotaet-pravila-borby-s-opasnostiu-sozdavaemoj-zhivotnymi-na-aerodromah.html?ysclid=lnzy38cgfh123313629> (accessed 09.13.2023).
8. AC 150/5200-33C: Hazardous Wildlife Attractants on or near Airports, FAA, 21 Feb. 2020.
9. FAA «Lessons Learned from Transport Airplane Accidents»: Bird Hazards.
10. World Birdstrike Association. Available at: <https://www.worldbirdstrike.com/about/mission-statement> (accessed 09.16.2023).
11. Recommended Practices No. 1. Standards For Aerodrome Bird/ Wildlife Control. International Birdstrike Committee. Available at:

<https://skybrary.aero/sites/default/files/bookshelf/4217.pdf> (accessed 09.18.2023).

12. International Birdstrike Committee. Available at: <https://int-birdstrike.org> (accessed: 09.21.2023).
13. «Miracle in the corn field». Available at: <https://www.pravilamag.ru/articles/118302-chudo-v-kukuruznom-pole-kak-piloty-a321-sovershili-pochti-nevozmozhnoe-deystvuyane-po-instrukcii/?ysclid=lnzyqgmwna347986185> (accessed 09.24.2023).
14. National Transportation Safety Board (January 21, 2009). NTSB Issues update on investigation into ditching of US Airways jetliner into Hudson River.
15. van Es, G.W.H. and H.H. Smith. 1999. A Method for Predicting Fatal Bird Strike Rates at Airports. NLR-CR-99322. Rijkswaterstaat, Directie Noordzee.
16. International Civil Aviation Organization (ICAO). Available at: <http://icao.int> (accessed 09.28.2023).
17. Ilyichev V.D. Zashhita samoletov i drugix obektov ot pticz. Ilyichev V.D. [et al.]; resp. ed. O. L. Silaeva. - Moscow: Partnership scientific. ed. KMK, 2007. - 319 p.
18. Jacobi V.E. Biologicheskie osnovy predotvrashheniya stolknovenij samolyotov s pticzami. M.: Nauka, 1974, 166 p.
19. Yudkin V.A., Grabovsky M.A. Kolichestvennyj metod ocenki ornitologicheskij obstanovki na aerodrome. Nauchnyi Vestnik MGTU GA, Moscow. Volume 21, No. 04, 2018. DOI: 10.26467/2079-0619-2018-21-4-48-59 (in Russian)
20. Elisov L.N., Ovchenkov N.I., Filippov V.L., Konyaev E.A., Laptev A.A. Sistemnyj podxod i chelovecheskij faktor v ornitologicheskij bezopasnosti aeroporta. Nauchnyi Vestnik MGTU GA. 2019;29:99-106.
21. Sharov V.D., Vorobiev V.V. Ogranicheniya po ispolzovaniyu matricy IKAO pri ocenke riskov dlya bezopasnosti poletov. Nauchnyi Vestnik MGTU GA. 2016;(225):179-187.
22. Guziy A.G., Kostina A.P. Metodologicheskij podxod k kolichestvennomu ocenivaniyu riska, obuslovlennogo stolknoveniem vozдушnyx sudov s pticzami. Nauchnyi Vestnik MGTU GA. 2022;25(5):12-24.
23. Guziy, A.G., Kapustin, A.G., Lushkin, A.M. & Fokin, A.V. (2019). Quantitative risk estimation methodology for flight safety in airline segment of commercial aviation. Civil Aviation High Technologies, vol. 22, no. 4, pp. 33–42.
24. Doc 9859: Safety Management Manual (SMM). 4th ed. ICAO, 2018.
25. Aviation rules. Part 139. Certification of airfields (AP-139): put into effect by order of the Ministry of Transport of the Russian Federation dated July 5, 1994 No. 48.
26. Federal aviation rules for flights in the airspace of the Russian Federation. FAP-136: put into effect by order of the Ministry of Defense of the Russian Federation, the Ministry of Transport of the Russian Federation and the Russian Aviation and Space Agency dated March 31, 2002 No. 136/42/51
27. Atkinson E.A., Banker R.D., Kaplan R.S., Jung M.S. Upravlencheskij uchyot. - St. Petersburg: Dialectics LLC, 2019. - 880 p. — ISBN 978-5-907144-70-5.
28. Vikhansky O. S. Strategicheskoe planirovanie: Uchebnik. Moscow. Moscow State University Publishing House. 1995
29. Kahneman, Daniel. Prospect Theory: An Analysis of Decision under Risk: Daniel Kahneman, Amos Tversky // *Econometrica* - 1979. - Vol. XVII.
30. Marchau Vincent A. W. J., Walker Warren E., Bloemen Pieter J. T. M., Popper Steven W. (Editors). Decision Making under Deep Uncertainty: From Theory to Practice. Springer, 2019 - 405 pp.
31. Course program «Special chapters of decision theory», The International Center of Decision Choice and Analysis (the DeCan center) of the National Research University Higher School of Economics (HSE University). Available at: <https://www.hse.ru/ba/bi/courses/646476187.html?ysclid=lguid580f586653943>, (accessed 26.09.2023)