JOURNAL
OF EUROPEAN ECONOMY
Vol. 20. № 1 (76). January–March 2021
Publication of West Ukrainian National University

Microeconomics

Dmytro BUGAYKO,
Yuri KHARAZISHVILI,
Viachelsav LIASHENKO,
Aleksy KWILINSKI

SYSTEMIC APPROACH TO DETERMINING THE SAFETY OF SUSTAINABLE DEVELOPMENT OF AIR TRANSPORT: INDICATORS, LEVEL, THREATS

Abstract

The article is dedicated to methods of integrating the safety of air transport in the mechanism of interaction between sustainable development goals and strategic management of sustanable development security through managerial,

Bugayko, Dmytro, Candidate of Economic Sciences, Associate Professor, Deputy Director of the Institute of International Cooperation and Education, National Aviation University, Kyiv, Ukraine. ORCID: 0000-0001-9901-4792 Email: bugaiko@nau.edu.ua.
Kharazishvili, Yuri, Doctor of Economic Sciences, Senior Researcher, Lead Researcher at the Department of Critical Infrastructure, Energy and Environmental Security, National Institute for Strategic Studies, Kyiv, Ukraine. ORCID: 0000-0002-3787-1323 Email: yuri_mh@ukr.net.
Liashenko, Viacheslav, Doctor of Economic Sciences, Professor, Head of the Department of Regulatory Policy and Entrepreneurship Development, Institute of Industrial Economics of National Academy of Sciences of Ukraine, Kyiv, Ukraine. ORCID: 0000-0001-6302-0605 Email: slaval.aenu@gmail.com.
Kwilinski, Aleksy, PhD, Habilitated Doctor in Economics, Professor, the London Academy of Science and Business, United Kingdom. ORCID: 0000-0001-6318-4001 Email: a.kwilinski@london-asb.co.uk.

functional, and informational links between subsytems of sustainable development and different hierarchal levels of safety. This determines the place and role of aviation safety in ensuring fundamental national interests, i.e. sustainable development of national economy. The multifactor hierarchal model detailing the level of safety of air transport was developed in accordance with the system approach in the context of sustainable development and combines the economic and technological, social, and environmental components. It is proposed to consider a total of 7 components and 29 indicators that include shadow economy aspects, without which the current conditions cannot be estimated accurately. The boundaries of safe existence have been defined for all indicators using Student's t-test. The conducted modelling has determined the current values of all indicators and the safety level of air transport as a whole. Identification has been carried out in accordance with the latest assessment methodology, including the multiplicative integral indices, modified method of normalization and formalized determination of dynamic weights. The list of threats and their severity have been determined using two criteria. Distance from the point of sustainable development, i.e. average value of the «homeostatic plateau», was used to identify the list and importance of threats, while the severity of threats was calculated using elasticity coefficients. The calculations show that the safety of air transport depends foremost on the social component, as well as economic and technological development of aviation.

Key words:

aircraft; sustainable development; aviation safety; indicators; boundaries of safe existence; integral index; threats.

JEL: O1, C440, C63, O17, R41, L93.

6 Figures, 4 Tables, 5 Formulae, 38 References.

Topicality of Research Topic

Ukraine is one of the ten countries with a full cycle of development, serial production, operation, technical support of aircraft, aircraft engines, avionics and training / retraining of aviation specialists. Ukraine has a developed system of air carriers, international airports and airfields, an air navigation service provider, organizations responsible for the development, serial production, maintenance of aircraft, a network of aviation logistics companies, etc. Thus, the development of air transport is undoubtedly a priority on the path to sustainable development of an independent state. Aviation is the calling card of our country on the world market and is an important lever for strengthening the influence and image of our state.

Air transport is part of the transport complex of Ukraine and an important component in the structure of the country's economy. It acts as a link between all components of economic security to ensure basic living conditions and development of the state and society. Aviation safety is an important component of the concept of general national security, personal safety, public safety and transport safety from external and internal threats. Maintaining an acceptable level of national air transport safety is a priority for the industry, as preserving human life and health, property, maintaining economic stability, social standards and ensuring environmental safety depends on addressing this challenge.

However, unfortunately, it can be argued that the potential of this system is currently only partially used. The lack of a single mechanism for strategic management of air transport safety in terms of sustainable development of the national economy is one of the deterrents to quality management of air transport. Objectively, this is due to the managerial, economic and technological diversity of air transport organizations, the difference in their forms of ownership and subordination, which creates certain chaotic trends in their development. On the other hand, it is indisputable that the poor synergy of air transport leads to significant, both PR and purely economic losses for the state.

In view of the above, the authors consider it prudent to apply a systematic approach to determining the level of safety in sustainable development of air transport, as well as to identifying major threats and to overcoming a range of crises that hinder the development of sustainable development of air transport.

The advantages of a systematic approach to safety management are an enhanced safety culture, a documented process approach to safety; better understanding of safety-related interfaces and relationships; improved early detection of safety threats; making decisions based on safety data; improved safety communication, prioritization of security, efficiency gains, possible financial savings and cost reductions. All of the above create the conditions for achieving a positive synergy effect for sustainable development of both air transport in particular and national economy as a whole.

Literature Review and Problem Statement

Specialists of the International Civil Aviation Organization conduct ongoing systematic research on the development of continuous monitoring of threats and advanced risk management of the aviation safety (International Civil Aviation Organization, 2016, 2019a, 2019b, 2019c; Convention on International Civil Aviation (Doc 7300); Convention on the International Organization of Civil Aviation, 2013). Other organizations that conduct similar research include International Air Transport Association (IATA), Airports Council International (ACI), Civil Air Navigation Services Organization (CANSO), International Coordinating Council of Aerospace Industries Associations (ICCAIA), Air Transport Action Group (ATAG), European Union Aviation Safety Agency, European Civil Aviation Conference (ECAC, 2020), European aviation safety agency EUROCONTROL, and other global and regional civil aviation organizations. Leading manufacturers of the aviation industry *Boeing* (2018) and *Airbus* (2014) make significant contributions to the analysis of integrated air transport safety and forecasting of the air transport market. The development of Ukrainian national aviation safety system is subject to the Law of Ukraine «On National Security of Ukraine» (No. 2469-VIII of 21.06.2018). Periodic monitoring of its activities is carried out by the State Statistics Service of Ukraine (2018), the Ministry of Infrastructure of Ukraine (2019) and the State Aviation Administration of Ukraine (2017). The National Bureau for Aviation Accidents Investigation of Ukraine analyses the state of flight safety based on the results of the investigation of aviation events and incidents with civil aircraft of Ukraine and foreign-registered vessels (2013, 2014, 2015, 2016, 2017, 2018, 2019).

Analysis of recent publications on this topic indicates a fairly deep but fragmentary nature of research on aspects of sustainable development of air transport. Scientists have studied the impact of risks on the effectiveness of ensuring economic security of air transport enterprises (Miziuk & Miziuk, 2016), have conducted structural analysis of financial stability factors of aviation enterprises (Solovei & Kostiunik, 2018).

A number of publications have been devoted to the sustainable development of the airport system. Ukraine partially introduced and implemented *State Target Program for the Development of Airports for the Period up to 2023* (Resolution of the Cabinet of Ministers of Ukraine No. 126 of 24.02.2016). Institutional aspects of airport development management were proposed, which included consideration of aspects of sustainable development (Hrinchenko, 2020). Notably, many authors have given foremost priority to aspects of environmental safety of airports. The results of the evaluation of environmental plans of European airports as an integral part of their sustainable development strategy were published (Dimitriou et al., 2014). Scientists have also proposed new approaches to

forecasting the development of civil aviation as part of the transport system of Ukraine (Petrovska & Havrylenko, 2011).

The search for new approaches to the analysis of conditions and assessment of aviation safety has attracted considerable attention from scientists. An analysis of the aviation safety system was performed using fractal and statistical tools (Bugayko et al., 2019), while theoretical approaches to measuring safety levels using the sequence factor test were proposed (Kharchenko et al., 2017).

According to the authors, the unresolved part of the problem requires research to take strategic view at the management sustainable development safety of air transport, as well as to develop effective tools for its implementation at the national level. Existing publications do not pay attention to the identification of the current level of aviation safety, in particular integrated assessment methods; do not develop the structure and system of indicators for assessing aviation safety, which is a necessary step before developing strategic scenarios for sustainable development that corresponds to sustable development goals.

The strategic vision of management of sustainable development safety of air transport involves first solving the problem of identifying the current level of safety, and then strategizing for a given period. This article is devoted to solving the problem of identifying the current level of safety of sustainable development of air transport in Ukraine.

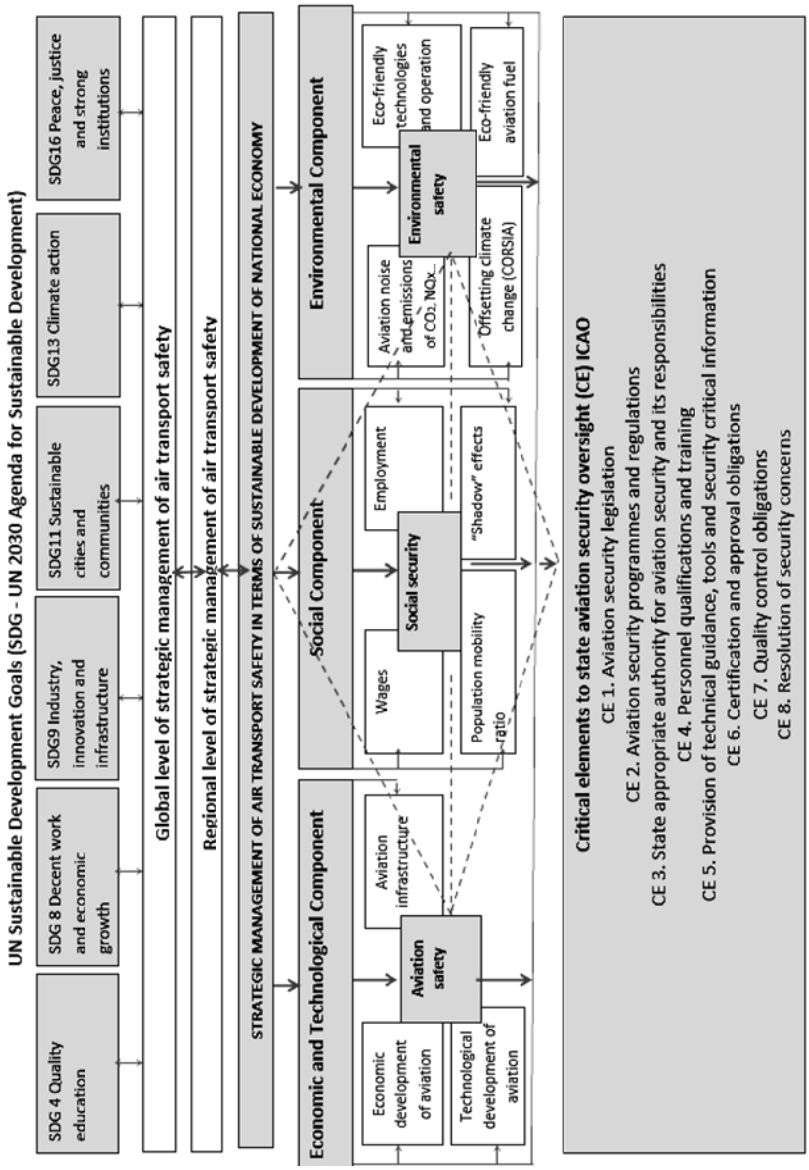
To solve these problems, the authors propose an organizational and economic mechanism for the interaction of sustainable development goals with strategic management of sustainable development safety of air transport (Bugayko & Kharazishvili, 2020) (fig. 1). This figure shows that the national aviation safety management system is an open integrated **system** that has a number of management, functional and information links with the subsystems of sustainable development and safety of different hierarchical levels.

In September 2015, world leaders gathered at the United Nations (UN) and adopted the 2030 Agenda for Sustainable Development. This action plan is aimed at achieving global sustainable development in the economic, social and environmental spheres and ensures that no UN member state is left out. The 17 Sustainable Development Goals (SDGs) set out in the 2030 Agenda can be used as benchmarks for the coordinated development of UN member states (Resolution of the UN General Assembly A/RES/70/1 of 25.09.2015). Air transport is an open system that is affected by a wide range of technical, natural, human and economic threats and risks. For its part, aviation is the generator of significant threats to the environment. Therefore, we cannot imagine air transport without looking for answers to the latest global challenges. Among the goals of sustainable development, air transport is directly related to achieving SDG4 Quality education; SDG8 Decent work and economic growth; SDG9 Industry, innovation and infrastructure; SDG11 Sustainable cities and communities; SDG13 Climate action; SDG16 Peace, justice and strong institutions.

English Edition. Vol. 20. № 1 (76). January–March 2021.
ISSN 2519-4070

Figure 1

Organizational and economic mechanism for the interaction of sustainable development goals with strategic management of sustainable development safety of air transport



Source: adapted from Bugayko & Kharazishvili (2020).

Through information links, the goals of sustainable development of air transport are connected with three hierarchical levels of strategic management of air transport safety: global, regional and national level. These levels are structurally interrelated through management (regions and countries mandatorily complying with the Standards and voluntarily complying with Recommended Practices of ICAO), functions (interaction of global, regional aviation organizations and national regulators / stakeholders) and information links (exchange of air safety information).

The national strategic management of aviation safety in the context of sustainable economic development should include the basic standards and recommended practices of the global level of strategic aviation safety management. They are developed by International Organization of Civil Aviation (ICAO), International Air Transport Association (IATA), Airports Council International (ACI), Civil Air Navigation Services Organization (CANSO). Regulations and regulatory requirements of the regional level of strategic management of air transport safety should also be taken into account (European Union Aviation Safety Agency (EASA), European Civil Aviation Conference (ECAC), European aviation safety agency EUROCONTROL, and other global and regional civil aviation organizations).

The main challenges for air transport lie in the development of air transport at the national, regional and global levels in the way that ensures the priorities of safety and security in economic, social and environmental spheres. Given the specifics of economic and technological development, social and environmental components of air transport, the authors propose the concept of *integrated national safety of air transport, which is the quintessence of aviation safety, social security and environmental safety, simultaneously achieving all components and indicators of sustainable development through strategic management. Functionally subordinated to various organizations of air transport*, aviation safety, social security and environmental safety are deeply interconnected by *information links*, as they characterize a single system of national air transport. The authors see their task in the *development of effective management links between different types of safety and security* on the basis of information links. This is the key to the state's implementation of an integrated system of preventative risk management, which is a priority of the ICAO Global Safety Plan.

At the national level, *information links of sustainable development goals* are the basis for a set of measures for the development of *functional and managerial links* aimed at systematically achieving goals at the national level and ensuring the appropriate contribution of the state at the regional and global levels.

SDG 4 Quality Education is ensured through management of the social component of AT. *SDG 8 Decent Work and Economic Growth* is achieved through management of the social component using the indicators of the level of wages in the production of air transport and the level of employment in air transport in Ukraine. *SDG9 Industry, Innovation and Infrastructure* is achieved by

managing the economic and technological component in the clusters «Economic Development of Aviation» and «Aviation Infrastructure». Here, the indicators include level of investment in air transport, level of exported services of air transport, level of imported air transport services, and ratio of domestic and international air transport. *SDG11 Sustainable Cities and Communities* is achieved by managing the economic and technological development, social and environmental components of air transport within the scope of systematic approach to determining the level of safety of sustainable development of air transport. Solving the problem of sustainable development of society is the quintessence of strategic management of air transport safety in terms of sustainable development of the national economy. *SDG13 Climate Action* is achieved through management of the environmental component with the help of indicators of CO2 emissions of Ukrainian air transport to GDP, the level of emissions of pollutants into the atmosphere, and the level of environmental costs of air transport. *SDG16 Peace, Justice and Strong Institutions* is achieved within the economic and technological component. Ukrainian air transport takes an active part in UN humanitarian missions, especially in unstable regions, achieves significant results in combating hunger and epidemics. A special role in this is played by Ukrainian transport airlines, among which the undisputed leader is the Antonov airline, which provides cargo transportation on the world's largest transport aircraft AN 225 «MRIYA» and AN-124 «RUSLAN».

The results of strategic management of integrated national aviation safety in the context of sustainable development of the national economy are achieved by the state through *managerial links*, good indicators of national oversight over aviation safety and ICAO Critical Elements, namely CE1-CE8.

The aim of the article is to ascertain the level of safety of sustainable development of Ukrainian air transport and to identify current threats from the standpoint of sustainable development.

Research Methods

Determining the safety level of sustainable development of air transport consists of several stages of the «concept of sustainable development» (Kharazishvili, 2019, pp. 41-46):

Determining the structure and system of indicators. This stage involves detailing the components and their indicators, the dynamics of indicators, as well as classifying them as stimulators (S – whose increase is desirable), or destimulators (D – whose decrease is desirable). Sustainable development of air transport is an integral characteristic of the economic system, as it includes a number of subsystems that are the most important interconnected structural

components of the economic system development and that reflect the functioning of certain areas of the subject of study: economic and technological, social, and environmental components (see Fig. 1).

As there is no single common system of sustainable development indicators in the world, each country that wants to implement a sustainable development strategy seeks to develop its own set of sustainability indicators. Therefore, most scientists currently disagree on the number of indicators and their content. In addition, there are other issues. In particular, there is no single reliable statistics database and the data on the same indicators often do not match. The lack of necessary statistics complicates the use of indicators in many countries. This means that the sustainable development strategy should also include the development of statistical services in countries transitioning to this strategy.

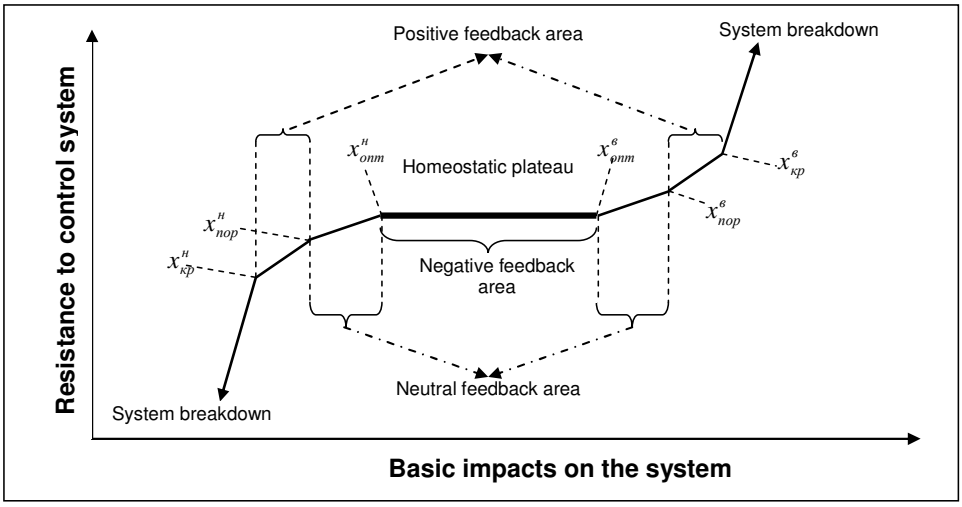
Strategic management of air transport safety in the context of sustainable development of the national economy includes three components, which are integrated in order to solve the **complex problem of ensuring the safety of sustainable development of air transport** (Bugayko & Kharazishvili, 2020). **The economic and technological component** includes economic and technological development, aviation infrastructure, and aviation safety during regular commercial, non-scheduled commercial and non-commercial flights, aviation training and training flights). **The social component** includes wages, employment level, population mobility rate, and «shadow» effects. The **environmental component** includes offsetting climate change (CORSIA), aviation noise and emissions of CO2, NOx…, eco-friendly technologies and operation, eco-friendly aviation fuel. A total of 29 indicators have been proposed, the list of which is not a dogma and may vary depending on the objectives and depth of the study.

Defining the boundaries of safe existence is the most important step in determining the level of safety. A systematic study of the problem of sustainable development from the standpoint of safety should include the definition of the boundaries of safe system operation, without the knowledge of which it is impossible to protect the vital safety interests. That is why for each indicator it is necessary to determine the *vector of threshold values*: lower critical ($x^{н}_{кр}$); lower threshold ($x^{н}_{пор}$); lower optimal ($x^{н}_{опт}$); upper optimal ($x^{в}_{опт}$); upper threshold ($x^{в}_{пор}$); upper critical ($x^{в}_{кр}$) (fig. 2).

A pair of optimal values determines the *homeostatic plateau*, within which there are the best conditions for system operation and negative feedback. The concept of «homeostatic plateau» was first proposed by Van Gigch (1978) in applied systems theory, which included the plateau itself and the breakdown of the system on both sides.

Figure 2

Extended homeostatic plateau of a dynamic system



Source: adapted from Kharazishvili (2019).

The concept of «homeostatic plateau» has been further developed in the work of Kharazishvili (2019, p.67) through the addition of a range of thresholds and critical values with the areas of neutral and positive feedback. Moreover, the change in the type of feedback does not occur immediately at the intersection of areas: first, the existing type of connection decreases exponentially, and then the other type of connection increases, likewise exponentially.

Among a number of methods for determining the vector of threshold values, it is possible to distinguish several that are most adequate and accessible. These include macroeconomic models that meaningfully reflect the effects of destabilizing factors on the conditions of a particular country in the current period; functional dependencies methods (Kaczynski, 2013) (macro / microeconomic analytical or statistical equations; Akhiezer-Goltz concept; information theory; «golden section»); stochastic methods (*t*-test; cluster analysis, fuzzy sets, logistic regression).

In the absence of a macromodel, the *t-test* is the most accessible of the stochastic methods. It involves constructing a probability density function for a given sample and calculating statistical characteristics: mathematical expectation, standard deviation and asymmetry coefficient. There is a variety of types of probability density functions for all indicators, however, it is possible to distin-

guish types with the most common modes distribution: normal, lognormal and exponential. Formulae for calculation of a vector of threshold values are defined for each of them (Table 1) (Kharazishvili, 2019, pp. 70–72) and distributions are further divided into *right-inclined* and *left-inclined* (Sukhodolya et al., 2020, p. 29).

Table 1

Formalized threshold vector values

Type of indicator probability density function	Lower threshold	Lower optimal value	Upper optimal value	Upper threshold
Normal	$\mu - t \times \sigma$	$\mu - \sigma$	$\mu + \sigma$	$\mu + t \times \sigma$
Longnormal *(right-inclined)*	$\mu - t \times \sigma / k_{as}$	$\mu - \sigma / k_{as}$	$\mu + \sigma$	$\mu + t \times \sigma$
Longnormal *(left-inclined)*	$\mu - t \times \sigma$	$\mu - \sigma$	$\mu + \sigma / k_{as}$	$\mu + t \times \sigma / k_{as}$
Exponential *(right-inclined)*	$\mu - \sigma / k_{as}$	μ	$\mu + \sigma$	$\mu + t \times \sigma$
Exponential *(left-inclined)*	$\mu - t \times \sigma$	$\mu - \sigma$	μ	$\mu + \sigma / k_{as}$

Note: For critical values, ±3σ or more are used instead of t for short samples.
Source: Kharazishvili, Yu. (2019). Systemic security of sustainable development: Assessment tools, reserves and strategic implementation scenarios: Monograph [in Ukrainian]. Institute of Industrial Economics, National Academy of Sciences of Ukraine.

Determining the level of safety of sustainable development of air transport requires a step-by-step integral convolution of indicators and their threshold values (Kharazishvili, 2019; Kharazishvili et al., 2020). According to modern assessment methodology, it involves:

Multiplicative form of the integral index (1):

$$I_t = \prod_{i=1}^{n} z_{i,t}^{a_i}; \quad \sum a_i = 1; \quad a_i \geq 0, \tag{1}$$

where I – integral index; z – normalized indicator; a – weighting factor.

Combined normalizing method (2):

$$S: z_i = \frac{x_i}{k_{норм}}, \qquad D: z_i = \frac{k_{норм} - x_i}{k_{норм}}, \quad k_{норм} > x_{\max}, \tag{2}$$

where x – indicator value; $k_{норм}$ – normalization factor; S – stimulator; D – destimulator.

Dynamic weights method (involves application of the principal component analysis and «sliding matrix» method) (3):

$$C_i \times D_i = \begin{pmatrix} d_1c_{11} + d_2c_{12} + ... + d_jc_{1j} \\ d_1c_{21} + d_2c_{22} + ... + d_jc_{2j} \\ .... \\ d_1c_{j1} + d_2c_{j2} + ... + d_jc_{jj} \end{pmatrix} = \begin{pmatrix} w_1 \\ w_2 \\ ... \\ w_j \end{pmatrix}, \quad a_i = \frac{w_i}{\sum w_i}, \tag{3}$$

where C – matrix of absolute values of factor loadings; D – vector matrix of variances; a – weighting factor.

Determining the list and severity of threats. Note that the most common ways to identify threats are based on the assessment of deviation of the integral indices of components and their safety indicators from the target values and the concept of risk:

Determining the list of threats by comparing the actual values of the integral indices of components and indicators with the target ones (sustainable development imbalance method). If we use the existing dynamics of indicators with the corresponding vectors of threshold values, integral indices of sustainable development and integral threshold values, we can calculate the deviation of integral indices of components and safety indicators of sustainable development of air transport from their average optimal values (homeostatic plateau), which can be considered the ***criteria for achieving safe sustainable development*** (Kharazishvili, 2019, p. 82). The set of threats is formed from a set of components and indicators of sustainable development that have the largest (critical) deviation from the «target» indicative value: the greater the deviation, the more significant the threat.

Since the identified threats are part of the integral indices of safe sustainable development and directly affect the level of safety, we can calculate the extent of their impact on the integral index of sustainable development. To do this, the coefficients of elasticity for each component and indicator are calculated. They characterize the extent of the impact of individual components and indicators on the level of sustainable development and are the necessary information for the development of priority measures. The elasticity coefficients of each component determine the change (in percent) in the dependent variable value (y) if the input variable value (x) is changed by 1% (4):

$$E = \frac{\Delta y}{\Delta x} \cdot \frac{x}{y}. \quad (4)$$

Thus, to determine the list of threats, two criteria are used: the distance from the point of sustainable development (the list and importance of threats are determined); the calculation of elasticity coefficients (degree of impact and severity of threats are determined).

Empirical Results and Discussion

Structure and system of indicators

This stage involves detailing the components and their indicators, the dynamics of indicators, as well as classifying them as stimulators (S – whose increase is desirable), or de-stimulators (D – whose decrease is desirable). The structure of sustainable development is developed taking into account the proposed organizational and economic mechanism of interaction of sustainable development goals with strategic management of safe sustainable development of air transport (Fig. 3).

The structure represents the appropriate hierarchy of subordinate components, taking into account the available macroeconomic indicators accessible in official sources of information and the possibility of calculation using macroeconomic models of general macroeconomic equilibrium (Table 2).

A distinctive feature of the proposed list of indicators is the presence of «shadow» indicators (the level of shadowing of air transport, the level of shadow capital utilization, the level of official GVA created by shadow wages, the level of shadow intermediate consumption), without which the assessment of sustainable development is inadequate.

The dynamics of the vast majority of indicators of air transport in Ukraine were determined according to official data of the State Statistics Service of Ukraine (2018).

Some indicators (share of air transport VA in transport and communications VA; ratio of investment in air transport to air transport output; coefficient of automation of air transport, share of value added in output; capital utilization ratio; level of renewal of fixed assets; level of wages in air transport manufacturing), which are not calculated by the State Statistics Service of Ukraine, were determined using the model of general macroeconomic equilibrium.

Figure 3

Components of sustainable development of air transport (hierarchal structure)

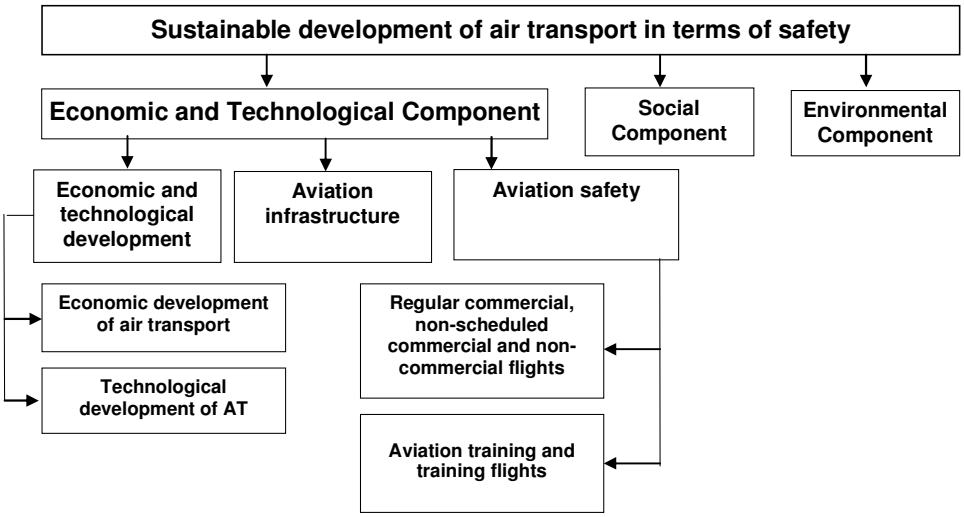


Table 2

Components and indicators of subsystems of sustainable development of air transport

Components	Indicators
1.1. Economic and technological development 1.1.1 *Economic development*	– share of air transport VA in transport and communications VA, % (S); – ratio of investment in air transport to air transport output, % (S); – ratio of exported air transport services to total export of transport services, % (S); – ratio of imported air transport services to total import of transport services, % (D); – ratio of shadow air transport to official air transport, % (D);
1.1.2. *Technological development*	– coefficient of automation of air transport, share of value added in output (S); – capital utilization ratio (S); – shadow capital utilization ratio, % of official utilization (D); – level of use of passenger capacity of airplanes and helicopters (S),%; – level of renewal of fixed assets, (S) %;

Components	Indicators
1.2 Aviation infrastructure	– cargo transport capacity of GDP by air transport (ratio of cargo turnover to GDP) (D); – passenger transport capacity of GDP by air transport (ratio of passenger turnover to GDP) (D); – average distance of cargo transportation (ratio of cargo turnover to volume of cargo transportation) (S); – average distance of passenger transportation (ratio of passenger turnover to the volume of passenger transportation) (S); – ratio of domestic and international air transport (S);
1.3. Aviation Safety 1.3.1. *Regular commercial, non-scheduled commercial and non-commercial flights*	– accident rates (crashes) (D); – accident rates (malfunctions) (D); – accident rates (serious incidents) (D);
1.3.2. *Aviation training and training flights*	– accident rates (crashes) (D); – accident rates (malfunctions) (D); – accident rates (serious incidents) (D);
2.1. Social component	– wages in Ukrainian air transport manufacturing (S); – employment in aviation (%the average number of full-time employees of air transport in relation to the total average number of full-time employees (transport, warehousing, postal and courier services)) (S); – population mobility rate (S); – ratio of official VA created by shadow wage to the official VA of AT,% (D); – ratio of shadow employment to official employment, % (D);
3.1. Environmental component	– ratio of CO2 emissions of Ukrainian air transport to GDP (D); – emissions of pollutants into the atmosphere (D); – environmental costs of aviation (S).

Determining the boundaries of safe existence

Formalized definition of the boundaries of safe existence – the vector of threshold values – eliminates subjectivity and significantly enhances the scientific and practical significance of the results. This is because their scientific substantiation makes it possible to more accurately identify potential «danger zones», as well as conditions for strengthening the economic immunity of the studied sys-

tem, which is achieved by comparing integral indices with integral thresholds and performing preventative risk management for all components of system of strategic management of aviation safety.

The paper uses an array of statistical data and indicators from national sources (State Statistics Service of Ukraine, 2018; Ministry of Infrastructure of Ukraine, 2019; State Aviation Administration of Ukraine, 2017; National Bureau for Aviation Accidents Investigation of Ukraine, 2013, 2014, 2015, 2016, 2017, 2018, 2019), and international sources (ICAO, 2016, 2019a, 2019b). These characterize the level and structure of sustainable development for the last 10 years. Additionally, results for indicators that are missing in official statistics were modelled and calculated by the authors. For specific indicators, the countries or regions (mainly countries) were selected because they have the best values of the respective indicators and can be a model for the future. A similar opinion is expressed by Academician E.M. Libanova (2014, p. 4), «When developing a hypothesis, it is necessary to take into account not only the current trends in their country, but also the parameters of their development in other countries, especially in those that can be considered as a reference for Ukraine.» Thus, determination of the vector of threshold values is similar to a construction of a hypothetical country (region) – a benchmark with the best level of sustainable development for all indicators (Grishnova & Kharazishvili, 2019, p.69).

Therefore, using these approaches, we obtain the vectors of the threshold values for indicators of sustainable development of air transport (Table 3).

Table 3

Vectors of threshold values for indicators of sustainable development of air transport

Components and indicators	Lower threshold	Lower optimal value	Upper optimal value	Upper threshold	Current value 2020
Economic development					
– share of air transport VA in transport and communications VA, % (S);	5,0	6,6	8.5	10,8	4,37
– ratio of investment in air transport to air transport output, % (S);	11,6	12,8	14,6	17,7	5,03
– ratio of exported air transport services to total export of transport services, % (S);	19,0	24,5	39,5	48,6	18,65

Components and indicators	Lower thresh-old	Lower optimal value	Upper optimal value	Upper thresh-old	Current value 2020
– ratio of imported air transport services to total import of transport services, % (D);	36	29	16	10,8	44,44
– ratio of shadow air transport to official air transport, % (D);	25	15	10	5	41
Technological development					
– coefficient of automation of air transport, share of value added in output (S);	0,47	0,51	0,56	0,65	0,458
– capital utilization ratio (S);	0,87	1,1	1,44	2,1	1,021
– shadow capital utilization ratio, % of official utilization (D);	17	10	7	3,5	41,97
– level of use of passenger capacity of airplanes and helicopters (S),%;	70	80	90	100	56
– level of renewal of fixed assets, (S) %;	4	6,6	10	15	5,21
Aviation infrastructure					
– cargo transport capacity of GDP by air transport (ratio of cargo turnover to GDP) (D);	0,00182	0,00155	0,00111	0,00061	0,00158
– passenger transport capacity of GDP by air transport (ratio of passenger turnover to GDP) (D);	0,07978	0,06686	0,03674	0,01875	0,0785
– average distance of cargo transportation (ratio of cargo turnover to volume of cargo transportation) (S);	2475	2963	3634	4462	3022
– average distance of passenger transportation (ratio of passenger turnover to the volume of passenger transportation) (S);	1800	1900	2200	2300	1142
– ratio of domestic and international air transport (S);	0,1274	0,1774	0,2429	0,3126	0,0921

Components and indicators	Lower thresh-old	Lower optimal value	Upper optimal value	Upper thresh-old	Current value 2020
Aviation safety:					
Regular commercial, non-scheduled commercial and non-commercial flights:*					
– accident rates (crashes) (D);	1,1561	0,7531	0,35	0,35	1,1118
– accident rates (malfunctions) (D);	1,5592	0,7531	0,35	0,35	0,35
– accident rates (serious incidents) (D);	2,4254	0,8131	0,41	0,41	0,41
Aviation training and training flights:*					
– accident rates (crashes) (D);	11,3	8,234	5,167	2,1	10,78
– accident rates (malfunctions) (D);	14,368	11,301	5,167	2,1	10,78
– accident rates (serious incidents) (D);	17,435	8,234	5,167	2,1	2,1
Social component					
– wages in Ukrainian air transport manufacturing (S);	0,2	0,26	0,32	0,382	0,0938
– employment in aviation, % (S);	80	90	98	100	73,15
– population mobility rate (S);	0,2	0,615	1,3	2,775	0,2
– ratio of official VA created by shadow wage to the official VA of AT,% (D);	15	8	5	3	56,67
– ratio of shadow employment to official employment, % (D);	23	14	6,5	3	53,49
Environmental component					
– ratio of CO2 emissions of Ukrainian air transport to GDP (D);	0,82	0,51	0,32	0,2	0,71
– emissions of pollutants into the atmosphere (D);	0,0123	0,0076	0,0048	0,003	0,0093
– environmental costs of aviation (S).	0,15	0,17	0,2	0,26	0,1113

Note*: To exclude zero values, current values of indicators and their threshold values were increased by 0.35; 0.35 and 0.41 respectively to maintain the proportions followed by a return to original values in reverse conversion.
Note**: To exclude zero values, current values of indicators and their threshold values were increased by 0.41; 0.41 and 0.41 respectively to maintain the proportions followed by a return to original values in reverse conversion.

Determining the level of safe sustainable development of air transport

Determining the level of safe sustainable development of air transport is conducted by applying the proposed methodology of integral assessment and simultaneous integral convolution for both indicators (I) and their threshold values (P), which is reflected in the multifactor hierarchical model (5).

$$\begin{cases} I_{CP\_AT,t} = I_{ек\_техн}^{a_{1,t}} \cdot I_{соц}^{a_{2,t}} \cdot I_{екол}^{a_{3,t}};\ P_i = \prod_{j=1}^{4} p_{ij}^{b_{ij}};\ p_{ij} = \left[p_{пор.,ij}^{нижнє}; p_{опт.,ij}^{нижнє}; p_{опт.,ij}^{верхнє}; p_{пор.,ij}^{верхнє}\right]; \\ I_{ек\_техн,t} = I_{ек-техн,t}^{a_{1,t}} \cdot I_{ав.інфрастр,t}^{a_{2,t}} \cdot I_{безп.авіації,t}^{a_{3,t}}; \\ I_{ек-техн,t} = I_{екон,t}^{a_{1,t}} \cdot I_{техн,t}^{a_{2,t}};\quad I_{екон,t} = \prod_{i=1}^{5} z_{екон,t}^{a_i};\quad I_{техн,t} = \prod_{i=1}^{5} z_{техн,t}^{a_i}; \\ I_{ав.інфрастр,t} = \prod_{i=1}^{5} z_{ав.інфрастр,t}^{a_i}; \\ I_{безп.авіації,t} = I_{полети,t}^{a_{1,t}} \cdot I_{роботи,t}^{a_{2,t}};\ I_{полети,t} = \prod_{i=1}^{5} z_{полети,t}^{a_i};\ I_{роботи,t} = \prod_{i=1}^{5} z_{роботи,t}^{a_i}; \\ I_{соц,t} = \prod_{i=1}^{5} z_{соц,t}^{a_i}; \\ I_{екол,t} = \prod_{i=1}^{3} z_{екол,t}^{a_i}; \end{cases} \quad (5)$$

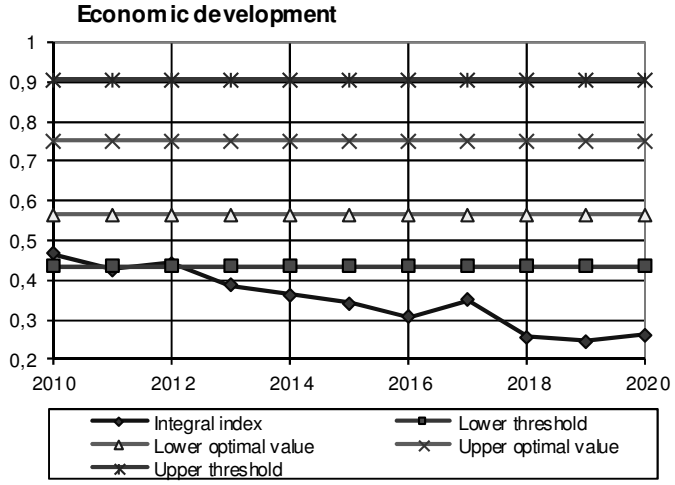
Modelling the dynamics of integral indices of components of sustainable development of air transport in comparison with integral threshold values, i.e. in the safety dimension, gives the following picture of the current state of air transport safety by components (Fig. 4).

According to calculations, the level of economic development (Fig. 4a) has a negative trend and is in the critical zone below the lower threshold since 2012, while the level of technological development (Fig. 4b) has left the optimal zone in 2018 and has also been in the critical zone since. These two components cause the negative trend of the economic and technological component of air transport and put it in the critical zone (Fig. 4c).

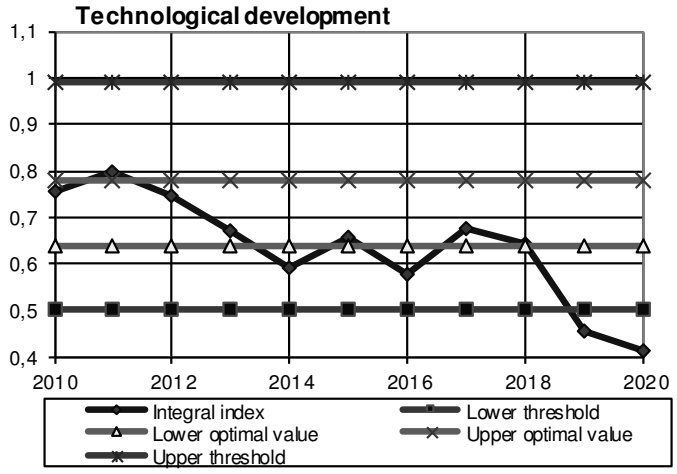
Similarly, the quality of aviation infrastructure (Fig. 4d) has been deteriorating since 2014 and is in the critical zone. Level of flight safety (Fig. 4e) is more or less satisfactory – below the optimal level, while safety during aviation training (Fig. 4f) is almost at the optimal level according to the indicators of crashes, malfunctions and serious incidents.

Figure 4

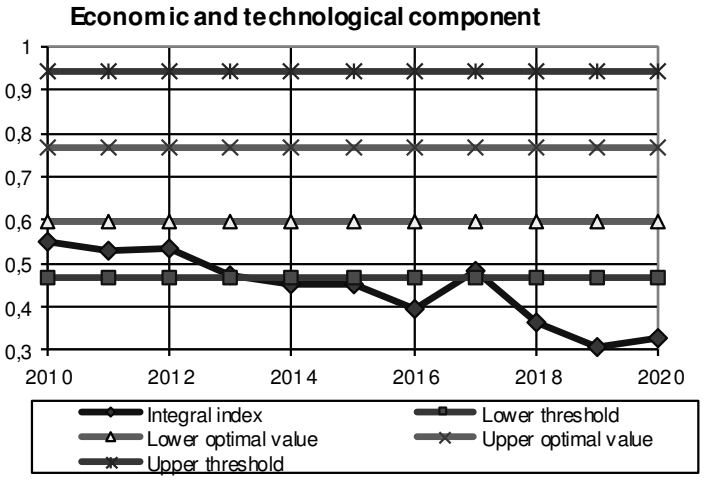
Dynamics of integral indices of safe sustainable development of air transport



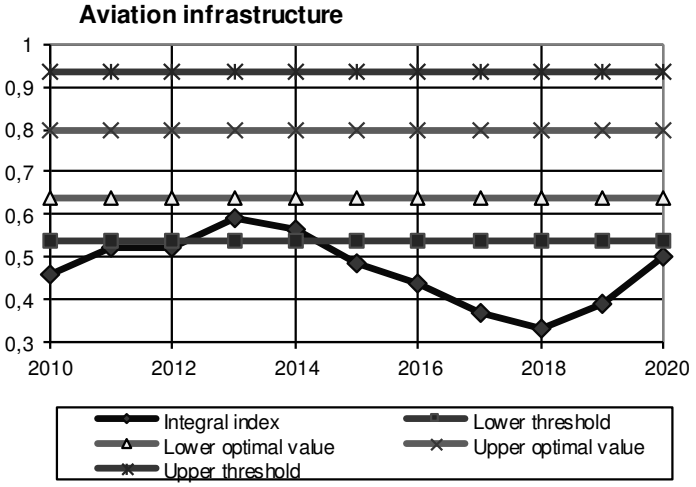
a



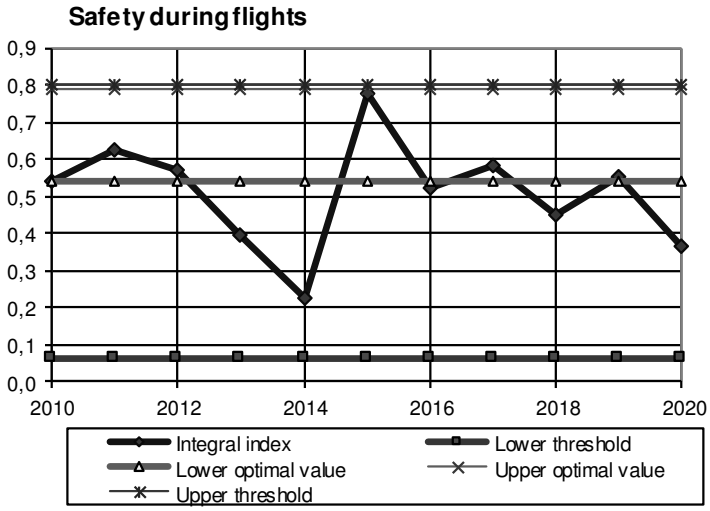
b


Economic and technological component
1
0,9
0,8
0,7
0,6
0,5
0,4
0,3
2010
2012
2014
2016
2018
2020
Integral index
Lower threshold
Lower optimal value
Upper optimal value
Upper threshold

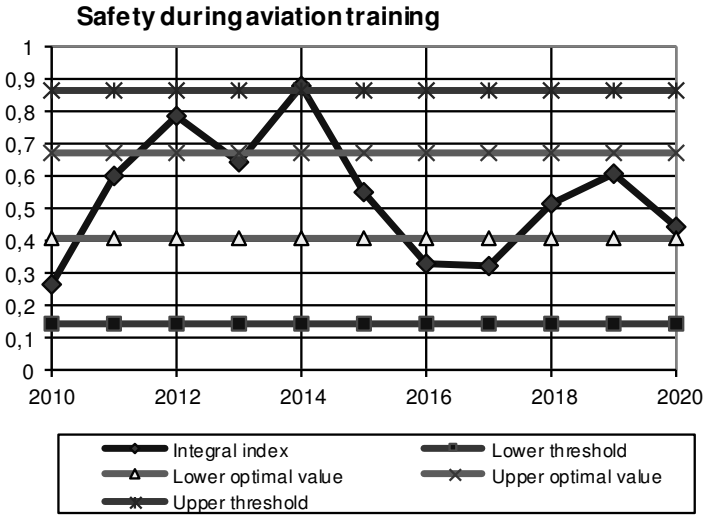
c


Aviation infrastructure
1
0,9
0,8
0,7
0,6
0,5
0,4
0,3
2010
2012
2014
2016
2018
2020
Integral index
Lower threshold
Lower optimal value
Upper optimal value
Upper threshold

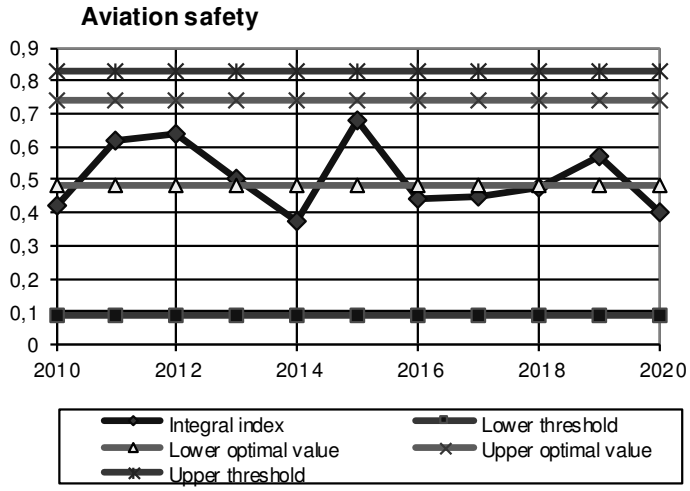
d


Safety during flights
0,9
0,8
0,7
0,6
0,5
0,4
0,3
0,2
0,1
0,0
2010
2012
2014
2016
2018
2020
Integral index
Lower threshold
Lower optimal value
Upper optimal value
Upper threshold

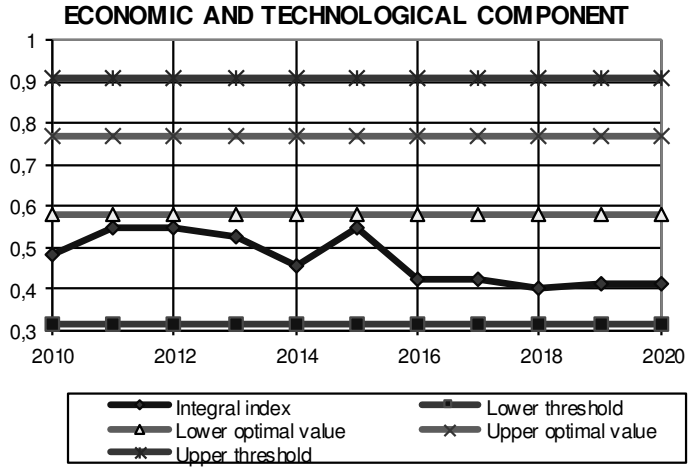
e


Safety during aviation training
1
0,9
0,8
0,7
0,6
0,5
0,4
0,3
0,2
0,1
0
2010
2012
2014
2016
2018
2020
Integral index
Lower threshold
Lower optimal value
Upper optimal value
Upper threshold

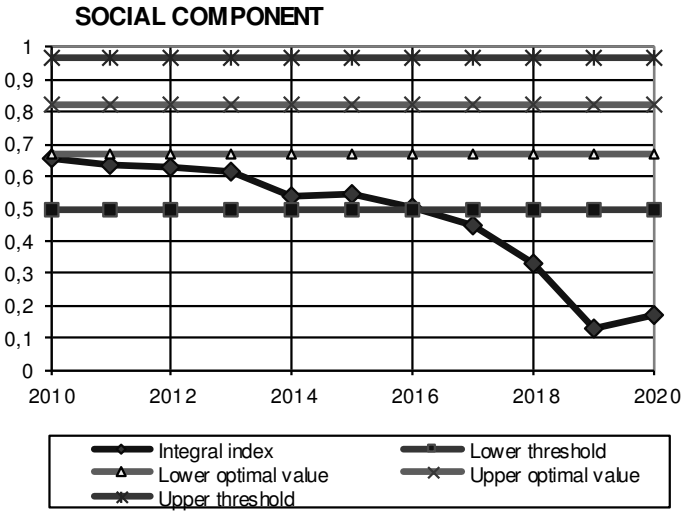
f


Aviation safety
0,9
0,8
0,7
0,6
0,5
0,4
0,3
0,2
0,1
0
2010
2012
2014
2016
2018
2020
Integral index
Lower threshold
Lower optimal value
Upper optimal value
Upper threshold

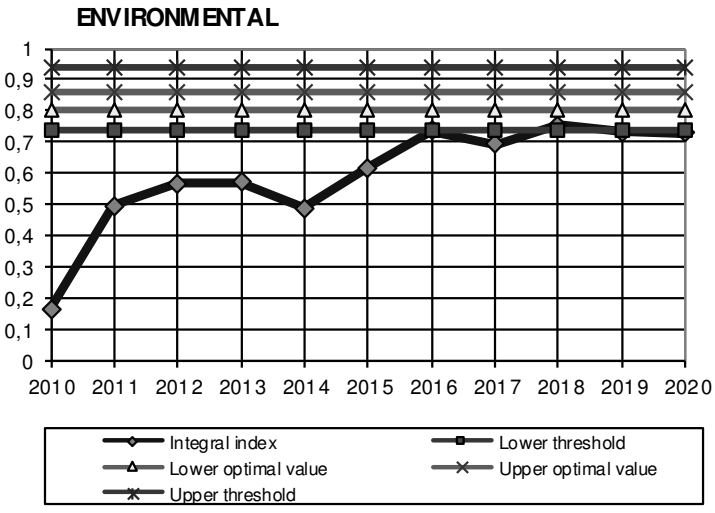
g


ECONOMIC AND TECHNOLOGICAL COMPONENT
1
0,9
0,8
0,7
0,6
0,5
0,4
0,3
2010
2012
2014
2016
2018
2020
Integral index
Lower threshold
Lower optimal value
Upper optimal value
Upper threshold

h


SOCIAL COMPONENT
1
0,9
0,8
0,7
0,6
0,5
0,4
0,3
0,2
0,1
0
2010
2012
2014
2016
2018
2020
Integral index
Lower threshold
Lower optimal value
Upper optimal value
Upper threshold

i


ENVIRONMENTAL
1
0,9
0,8
0,7
0,6
0,5
0,4
0,3
0,2
0,1
0
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020
Integral index
Lower threshold
Lower optimal value
Upper optimal value
Upper threshold

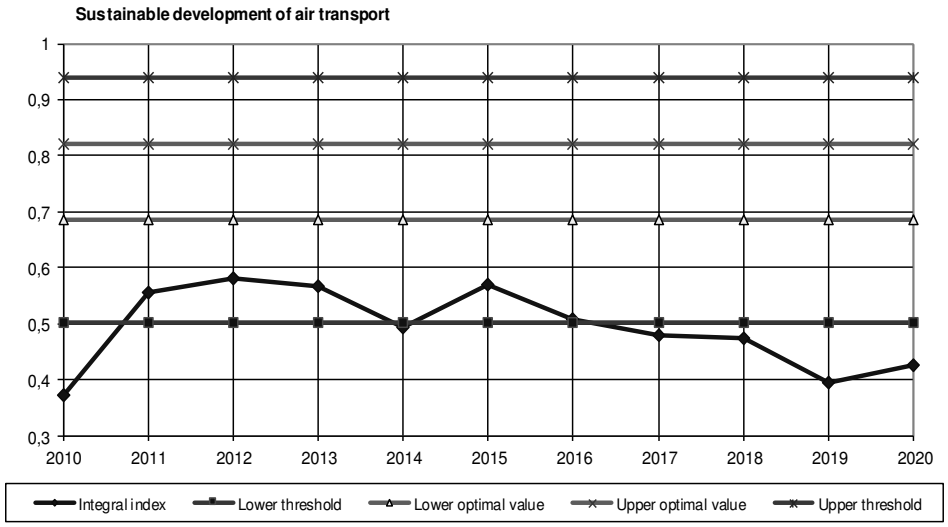
j

Unfortunately, all these components put the economic and technological component in the crisis zone – between the lower optimal and lower threshold values. The situation is much worse with the social component (Fig. 4i), which has a negative trend and is in the critical zone (below the lower threshold), as well as with the environmental component, which is also in the critical zone but has a positive trend. In addition, some improvement in the aggregate indicators such as «economic-technological development», «aviation infrastructure» and «social component» reflects a general decline in the economy and a decrease in demand, rather than a real improvement in the corresponding indicators.

Performing the next, final, integral convolution of the three components of sustainable development (economic and technological, social and environmental) both for the components and for their thresholds, we obtain the trend of the integral index for safe sustainable development of air transport compared to the integral thresholds. This allows us to identify the current level of safety, which is critical (Fig. 5).

Figure 5

Dynamics of the integral index for safe sustainable development of air transport



In general, the situation with the dynamics of integral indices of components and the overall level of sustainable development of air transport show a general rapid decline in the institutional and managerial capacity of the country to implement the policy of ensuring the desired level of safe sustainable development.

The trends in integral indices compared to integral thresholds are a clear indication of the effectiveness of policy in this area. The task of the policy is to move the integral index first into the crisis (orange) zone – between the lower threshold and the lower optimal value, and then into the optimal (green) zone of sustainable development. This is achieved through the introduction of appropriate measures. Thus, the comparison of integral indices with integral threshold values translates the concept of «development» into the concept of «safety».

Determining the list and severity of threats

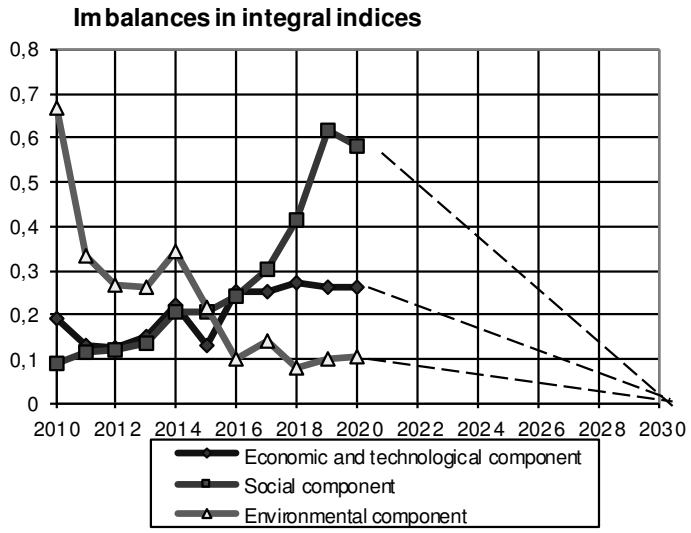
The existing dynamics of indicators, integral indices of sustainable development and integral thresholds are used to determine the list of threats by the criterion of distance from the indicator of sustainable development (average optimal value – homeostatic plateau), taking into account the projected level of sustainable development in 2030 (Fig. 6).

The calculations (Fig. 4-6) reflect the current level of safety of sustainable development of air transport and illustrate which components and relevant indicators fall short of the safe level of sustainable development and, accordingly, pose a threat to safe sustainable development of air transport according to the criterion of distance from the point of sustainable development (as of the end of 2020). For example, at the level of the main subsystems of sustainable development, the list of important threats is defined as follows (Fig. 5a): social, economic and technological, environmental components. The use of the second criterion (severity of impact) makes it possible to determine the extent of a threat's impact through the calculation of coefficients of elasticity. A clearer picture of imbalances and a list of threats by importance can be obtained from the relevant indicators of each component of the relevant subsystem.

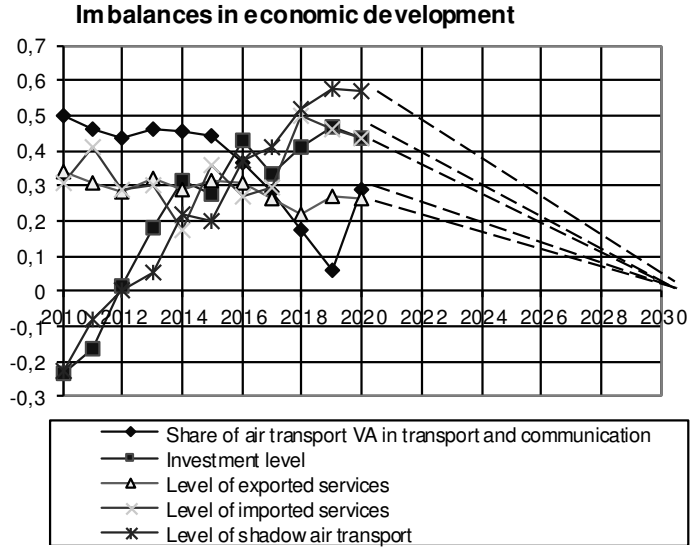
The most important task of sustainable development is to eliminate imbalances, i.e. to reduce the deviation of each component of sustainable development to zero, for example, by the end of 2030. Elimination of disproportions and minimizing of deviations from the criterion of sustainable development will ensure balanced sustainable development.

Figure 6

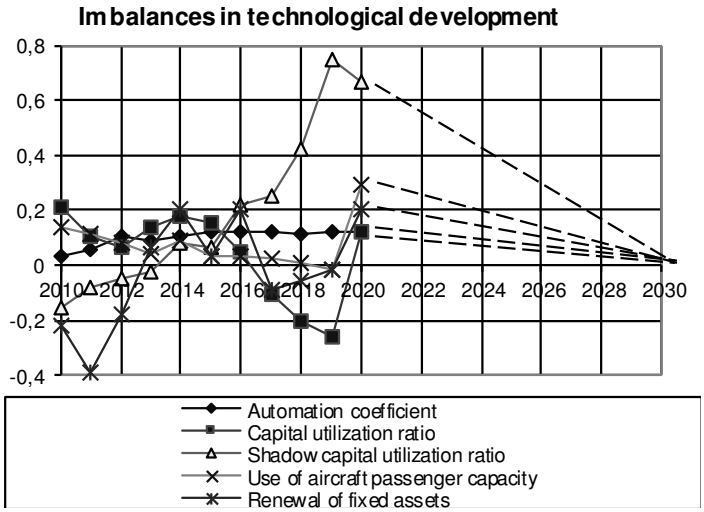
Deviations of integral indices from the criteria of sustainable development



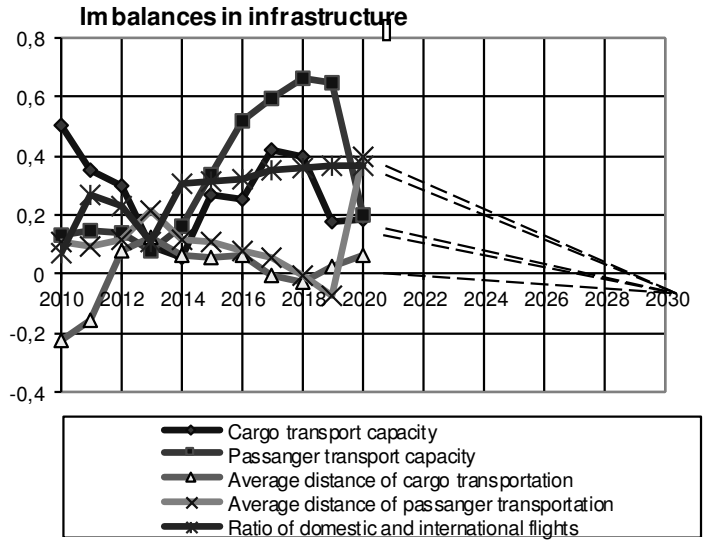
a



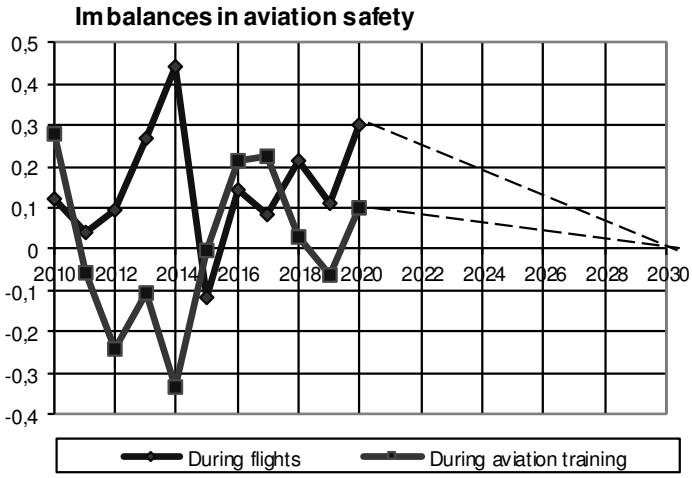
b


Imbalances in technological development
0,8
0,6
0,4
0,2
0
-0,2
-0,4
2010 2012 2014 2016 2018 2020 2022 2024 2026 2028 2030
Automation coefficient
Capital utilization ratio
Shadow capital utilization ratio
Use of aircraft passenger capacity
Renewal of fixed assets

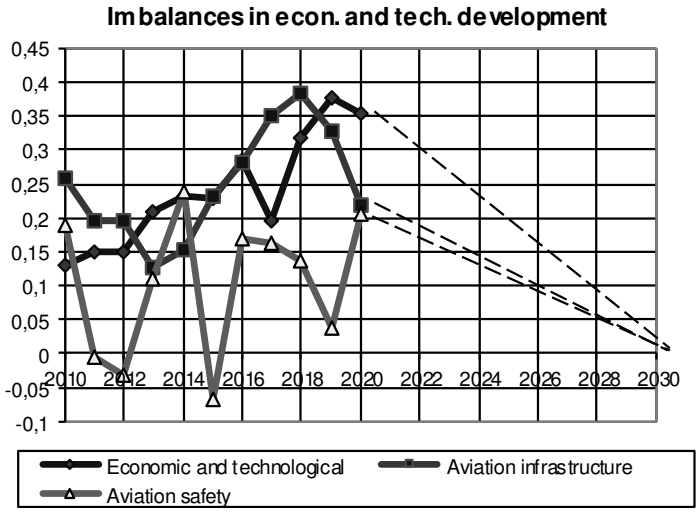
c


Imbalances in infrastructure
0,8
0,6
0,4
0,2
0
-0,2
-0,4
2010 2012 2014 2016 2018 2020 2022 2024 2026 2028 2030
Cargo transport capacity
Passanger transport capacity
Average distance of cargo transportation
Average distance of passanger transportation
Ratio of domestic and international flights

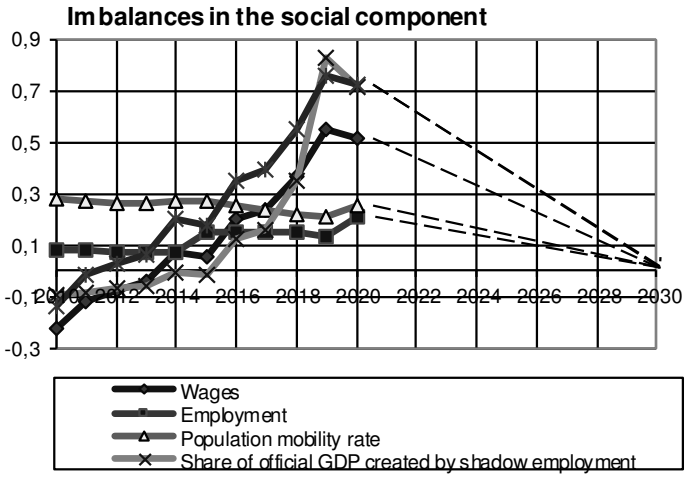
d


Imbalances in aviation safety
0,5
0,4
0,3
0,2
0,1
0
-0,1
-0,2
-0,3
-0,4
2010 2012 2014 2016 2018 2020 2022 2024 2026 2028 2030
During flights
During aviation training

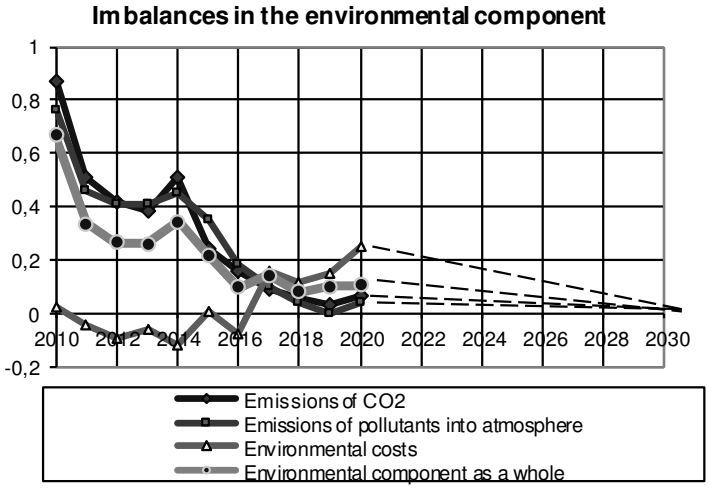
e


Imbalances in econ. and tech. development
0,45
0,4
0,35
0,3
0,25
0,2
0,15
0,1
0,05
0
-0,05
-0,1
2010 2012 2014 2016 2018 2020 2022 2024 2026 2028 2030
Economic and technological
Aviation infrastructure
Aviation safety

f


Imbalances in the social component
0,9
0,7
0,5
0,3
0,1
-0,1
-0,3
2010 2012 2014 2016 2018 2020 2022 2024 2026 2028 2030
Wages
Employment
Population mobility rate
Share of official GDP created by shadow employment

g


Imbalances in the environmental component
1
0,8
0,6
0,4
0,2
0
-0,2
2010 2012 2014 2016 2018 2020 2022 2024 2026 2028 2030
Emissions of CO2
Emissions of pollutants into atmosphere
Environmental costs
Environmental component as a whole

h

The list of ten most critical threats (indicators below the lower threshold) by distance from the criterion of sustainable development (importance of threats) and the severity of their impact on the safety of air transport achieved through the calculation of elasticity factors are given in table 4.

Table 4

Critical threats and the severity of their impact on the safety of sustainable development of air transport

Components and indicators of the safety level – threats by distance from the criterion of sustainable development (importance of the threat)	Components and indicators of the safety level – threats by severity of impact	Elasticity coefficient
By components		
1. Social	1. Environmental	0,3959
2. Economic development	2. Social	0,2264
3. Technological development	3. Aviation infrastructure	0,1340
4. Flight safety	4. Flight safety	0,0672
5. Aviation infrastructure	5. Aviation training safety	0,0664
6. Environmental	6. Economic development	0,0543
7. Aviation training safety	7. Technological development	0,0525
By indicators		
1. Level of shadow intermediate consumption	1. Level of shadow intermediate consumption	-0,4324
2. Ratio of official VA created by shadow wages	2. Accidents rates (crashes) during flights	-0,3024
3. Shadow capital utilization ratio	3. Ratio of official VA created by shadow wages	-0,2174
4. Level of shadow air transport	4. level of investment into environment	0,0802
5. Share of wages in output	5. Accidents rates (crashes) during training flights	-0,0741
6. Level of imported services	6. Level of imported services	-0,0709
7. Ratio of investment to output	7. Share of wages in output	0,0502
8. Average distance of passenger transportation	8. Population mobility rate	0,0470
9. Ratio of domestic and international flights	9. Shadow capital utilization ratio	-0,0454
10. Use of aircraft capacity	10. Accidents rates (malfunctions) during training flights	-0,0424

Analysis of the calculations shows that 5 of the 7 components of air safety are the most critical, i.e. are in the red zone – below the lower threshold. These are *social component, economic development, technological development, aviation infrastructure, environmental component.* One component (*flight safety*) is in the orange (crisis) zone, another (*aviation training safety*) is in the green (optimal) zone. The results are even worse in terms of indicators, as out of 29 total, eighteen (62%) are in the red and present critical threats, six indicators are in the orange (crisis) zone, and only 5 indicators are in the green (optimal) zone.

Therefore, the components and indicators that are in the critical zone are the main threats to safety of sustainable development of air transport. They influence the level of safety to a great extent, which is why they should be given particular consideration during reforms. In fact, **monitoring the integral indices of safety levels of sustainable development of air transport is the most effective assessment tool for determining the efficiency of governmental and state actions**. It is better than mere comparison of separate macro-indicators that leaves out all others. Therefore, government's first priority should be changing the dynamics of components and indicators from positive to negative, in order to ensure their movement to the optimal zone. This should become an objective gauge of reform's effectiveness in any area of safety.

Conclusions and Directions for Future Research

The authors propose an organizational and economic mechanism for the interaction of sustainable development goals with strategic management to solve the problems of strategic management of safe sustainable development of air transport. It follows that the national system of managing air transport safety is an open integrated **system** that has a number of management, functional and information links to the subsystems of sustainable development and different hierarchical levels of safety.

Economic and technological, social and environmental components are combined in the proposed model for determining the level of air transport safety based on the application of a systems approach in the context of sustainable development. It is proposed to consider a total of 29 indicators that include shadow economy aspects, without which the current conditions cannot be estimated accurately. The boundaries of safe existence – vectors of threshold values – have been defined for all indicators using functions of probability density, calculation of statistical characteristics, determination of affiliation to the type of distribution and formalized calculation of Student's t-test. This presentation makes it possible to identify the level of safety of sustainable development of air transport as a state of security and the ability of the system to adapt to new challenges.

To solve the problem of determining the level of safety, a universal methodology of identification and strategizing in the field of national security is used, which allows us to compare indicators of different security areas and substantiate strategic scenarios of security development. The methodology is based on the concept of sustainable development from the standpoint of security, which provides for the definition of the boundaries of safe existence (vector of threshold values) and justification of the criterion of sustainable development as the average value of «homeostatic plateau».

An integrated multifactor model of air transport safety in the context of sustainable development has been developed. Simulations were performed to identify the existing level of safety both for individual components and for the safety of air transport in general. The results indicate a critical level of safety – the integrated index is below the value of lower threshold. Of the 29 indicators, 18 (62%) are in the red zone and pose a critical threat, 6 indicators in the orange (crisis) zone and only 5 indicators are in the green (optimal) zone.

The list of the most important threats is determined by distance from the criterion of sustainable development, and first places are occupied by «shadow» indicators. This leads to the conclusion that without a significant reduction in the level of shadowing and corruption in the country, achieving the desired level of safety for the sustainable development of either air transport or national security is impossible. The significance of the impact of threats on the overall level of air transport safety was determined in order to develop appropriate institutional measures to respond to identified threats.

The calculations show that the safety of air transport foremost depends on the social component, as well as economic and technological development of air transport.

Considering the classical forecasting principle of «the past determines the future» unacceptable for strategizing in this case, in the context of future research, a new approach to strategic planning is proposed, based on the principle «the future is determined by the trajectory into the future». It consists first in determining the distance between the criterion of sustainable development (the average value of the «homeostatic plateau») and the integrated security index, setting the trajectory of achieving desired goals (strategic scenarios) and solving the problem of synthesizing the necessary values of components and indicators. The latter can be done using the methods of adaptive control from the theory of control by solving the inverse problem that provides the desired trajectory of air transport safety in the context of sustainable development (Kharazishvili, 2019).

References

AIRBUS S.A.S. (2015). *Commercial aviation accidents 1958 – 2014. A statistical analysis*. AIRBUS S.A.S.

Boeing. (2018). *Commercial Market Outlook 2019 –2038*.

Bugayko, D., Leshchynskyi, O., Sokolova, N., Isaienko, V., & Zamiar, Z. (2019). Analysis of the Aviation Safety Management System by Fractal and Statistical Tools. *Logistics and Transport*, *44*, 41-60.

Bugayko, D., & Kharazishvili, Y. (2020). Theoretical foundations of the aviation industry strategic safety management in the context of ensuring sustainable development of the national economy [in Ukrainian]. *Visnyk ekonomichnoi nauky Ukrainy, 1*(38), 166-175. https://doi.org/10.37405/1729-7206.2020.1(38).166-175

Convention on International Civil Aviation (Doc 7300), signed at Chicago on December 7, 1944.

Convention on the International Organization of Civil Aviation. Annex 19. «Flight Safety Management», 2013.

Dimitriou, D., Voskaki, A., & Sartzetaki, M. (2014). Airports Environmental Management: Results from the Evaluation of European Airports Environmental Plans. *International Journal of Information Systems and Supply Chain Management, 7*(1), 1-14. https://doi.org/10.4018/IJISSCM.2014010101.

European Civil Aviation Conference. (2020, November). *ECAC Policy Statement in the field of Civil Aviation Facilitation* (Doc 30, Part I – 12th Edition / May 2018, Amendment n 4).

Grishnova, O., & Kharazishvili, Y. (2019). Demographic security of Ukraine: Indicators, level, threats [in Ukrainian]. *Demography and social policy*, *2*, 65-80.

Hrinchenko, Yu. (2020). Airport development policy: Institutional aspects [in Ukrainian]. *Time Description of Economic Reform*, *1*, 91 – 99.

International Civil Aviation Organization. (2016). *2016-2030 Global Air Navigation Plan* (Doc 9750-AN/963) (5th ed.).

International Civil Aviation Organization. (2019a). *Aviation benefits report 2019*. https://www.icao.int/sustainability/Documents/AVIATION-BENEFITS-2019-web.pdf

International Civil Aviation Organization. (2019b). *ICAO Global Safety Plan for 2020-2022*.

International Civil Aviation Organization. (2019c). *The safety management manual* (Doc 9859) (4th ed.).

Kaczynski, A. B. (2006). *Principles of system security analysis of complex systems* [in Ukrainian]. DP »NVC «EUROATLATIC-INFORM).

Kaczynski, A. B. (2013). *Indicators of national security: Definition and application of their limit values: Monograph* [in Ukrainian]. NISD.

Kharazishvili, Yu. (2019). *Systemic security of sustainable development: Assessment tools, reserves and strategic implementation scenarios: Monograph* [in Ukrainian]. Institute of Industrial Economics, National Academy of Sciences of Ukraine.

Kharazishvili, Yu., Kwilinski, A., Grishnova, O., & Dzwigol, H. (2020). Social Safety of Society for Developing Countries to Meet Sustainable Development Standards: Indicators, Level, Strategic Benchmarks (with Calculations Based on the Case Study of Ukraine). *Sustainability*, *12*(21), 8953.

Kharchenko, V., Bugayko, D., Antonova, A., Grigorak, M., & Pawęska, M. (2017). Theoretical approaches for safety levels measurements–sequential probability ratio test (SPRT). *Logistics and transport*, *34*, 25 – 31.

Law of Ukraine No. 2469-VIII of 21.06.2018 «On National Security of Ukraine» [in Ukrainian]. https://zakon.rada.gov.ua/laws/show/2469-19

Libanova, E.M. (2014). Demographic shifts in social development context [in Russian]. *Demography and Social Economy*, *1*, 9-23.

Ministry of Infrastructure of Ukraine. (2019). *Report of the Head of the State Aviation Service of Ukraine for 2019* [in Ukrainian]. https://www.kmu.gov.ua/storage/app/sites/1/17-civik-2018/zvit_2019/zvit-2019-avia.pdf

Miziuk, V., & Miziuk, S. (2016). Influence of risks on the efficiency of ensuring the system of economic security of air transport enterprises [in Ukrainian]. *Proceedings of the National Aviation University*, *66*(1), 61-69. https://doi.org/10.18372/2306-1472.66.9935

National Bureau for Aviation Accidents Investigation of Ukraine. (2014). *Analysis of the state of aviation safety based on the results of the investigation of aviation accidence and incidents with civil aircraft of Ukraine in 2013* [in Ukrainian]. http://nbaai.gov.ua/wp-content/uploads/2020/05/analysis_2013_2.pdf

National Bureau for Aviation Accidents Investigation of Ukraine. (2015). *Analysis of the state of aviation safety based on the results of the investigation of aviation accidence and incidents with civil aircraft of Ukraine in 2014* [in Ukrainian]. http://nbaai.gov.ua/wp-content/uploads/2020/05/analysis_5.pdf

National Bureau for Aviation Accidents Investigation of Ukraine. (2016). *Analysis of the state of aviation safety based on the results of the investigation of aviation*

accidence and incidents with civil aircraft of Ukraine in 2015 [in Ukrainian]. http://nbaai.gov.ua/wp-content/uploads/2020/05/analysis2015.pdf

National Bureau for Aviation Accidents Investigation of Ukraine. (2017). *Analysis of the state of aviation safety based on the results of the investigation of aviation accidence and incidents with civil aircraft of Ukraine and foreign-registered aircraft in 2016* [in Ukrainian]. http://nbaai.gov.ua/wp-content/uploads/2020/05/analysis_2016.pdf

National Bureau for Aviation Accidents Investigation of Ukraine. (2018). Analysis of the state of aviation safety based on the results of the investigation of aviation accidence and incidents with civil aircraft of Ukraine and foreign-registered aircraft in 2017 [in Ukrainian]. http://nbaai.gov.ua/wp-content/uploads/2020/05/analysis_2017.pdf

National Bureau for Aviation Accidents Investigation of Ukraine. (2019). Analysis of the state of aviation safety based on the results of the investigation of aviation accidence and incidents with civil aircraft of Ukraine and foreign-registered aircraft in 2018 [in Ukrainian]. http://nbaai.gov.ua/wp-content/uploads/2020/05/analysis2018.pdf

National Bureau for Aviation Accidents Investigation of Ukraine. (2020). Analysis of the state of aviation safety based on the results of the investigation of aviation accidence and incidents with civil aircraft of Ukraine and foreign-registered aircraft in 2019 [in Ukrainian]. http://nbaai.gov.ua/wp-content/uploads/2020/05/analysis2019.pdf

Petrovska, S., & Havrylenko, A. (2011). Forecasting the development of civil aviation as a component of the transport system of Ukraine [in Ukrainian]. *Problems of Systemic Approach in the Economy*, *38*, 3 – 11.

Resolution of the Cabinet of Ministers of Ukraine No.126 of 24.02.2016 «State target program for the development of airports for the period up to 2023» [in Ukrainian]. http://zakon3.rada.gov.ua/laws/show/126-2016-%D0%BF

Resolution of the UN General Assembly A/RES/70/1 of 25.09.2015 «Transforming our world: the 2030 Agenda for Sustainable Development».

Solovei, N., & Kostiunik, O. (2018). Analysis of financial stability factors of aviation enterprises [in Ukrainian]. *Scientific Bulletin of Mukachevo State University. Series «Economics»*, *2*, 140-143. http://nbuv.gov.ua/UJRN/nvmdue_2018_2_23

State Aviation Administration of Ukraine. (2017). *Results of the aviation industry of Ukraine for 2016* [in Ukrainian]. https://avia.gov.ua/wp-content/ uploads/2017/04/Pidsumky-roboty-2016.pdf

State Statistics Service of Ukraine. (2019). *Transport and Communications of Ukraine 2018* [in Ukrainian]. http://www.ukrstat.gov.ua/druk/publicat/kat_u/2019/zb/08/zb_tr2018pdf.pdf

Sukhodolia, O., Kharazishvili, Yu., & Bobro, D. (2020). Methodological basis for assessing the level and strategic planning of the energy security of Ukraine [in Ukrainian]. *Economy of Ukraine*, *6*, 20–42. https://doi.org/10.15407/economyukr.2020.06.020

Van Gigch, J. (1978). *Applied general systems theory*. Harper & Row.

Received: January 15, 2021.
Revised: January 30, 2021
Accepted: February 2, 2021.