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IDENTIFICATION OF AIR TRANSPORT ECOLOGICAL COMPONENT LEVEL IN THE CONTEXT OF ENSURING SUSTAINABLE DEVELOPMENT OF THE NATIONAL ECONOMY

Dmytro Bugayko. Yuri Kharazishvili, Anna Antonova, Zenon Zamiar. "Identification of air transport ecological component level in the context of ensuring sustainable development of the national economy". *Aviation safety is an important component of the concept of general national security, the system of personal security, ecological and public safety and transport safety from external and internal threats. Maintaining an acceptable level of national aviation safety is a priority for the industry. In the context of globalization, ecological safety is becoming especially important. World leaders gathered at the United Nations (UN) and adopted the 2030 Agenda for Sustainable Development. It is a plan of action aimed at achieving global sustainable development in economic, social and environmental areas, which ensures that no UN member state* *is left behind. The 17 sustainable development goals on the 2030 Agenda can be used as benchmarks for the coordinated development of UN member states. One of the most important goals for the global survival of humankind is Goal 13 "Climate Change". In order to find an adequate answer to this challenge, the International Civil Aviation Organization (ICAO) has identified the following areas that can contribute to the attainment of the global aspirational goal: aircraft related technology and standards; improved air traffic management and operational improvements, development and deployment of sustainable aviation fuel and the Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA). The implementation of CORSIA is carried out not only at the global level, the initiative requires the search for effective management solutions at the national level. Statistics on the activities of the aviation industry of Ukraine indicate its stable development. However, unfortunately, the dynamic growth of air traffic entails an increase in emissions of chemical elements into the atmosphere, which are a real threat to the environment and can contribute to climate change processes. The main tool for ensuring ecological safety tasks is proactive risk management. The development of proactive tools for environmental risk management is relevant and has practical implications for sustainable development, both in the industry in particular and for the state as a whole. The articles offer the author's approaches to the identification of air transport ecological component level.*

Keywords: ecological safety; proactive civil aviation risk management; sustainable development of the national economy; carbon offsetting and reduction scheme for international aviation (CORSIA); identification of air transport ecological component level.

Дмитро Бугайко, Юрій Харазішвілі, Анна Антонова, Зенон Заміар. "Ідентифікація рівня екологічної складової авіаційного транспорту з метою забезпечення сталого розвитку національної економіки." *Безпека авіаційної галузі є важливою складовою концепції загальної національної безпеки, системи забезпечення особистої безпеки, екологічної безпеки суспільства та безпеки на транспорті від зовнішніх та внутрішніх загроз. Підтримка прийнятного рівня безпеки національної авіації є пріоритетним завданням галузі. Особливого значення в умовах глобалізації набуває екологічна безпека. Міжнародна організація цивільної авіації (ICAO) з огляду на динамічні глобальні зміни клімату, пропонує програму компенсацій та скорочення викидів діоксиду вуглецю для міжнародної авіації (CORSIA). Основним інструментарієм забезпечення цих завдань є випереджаюче управління ризиками. Розробка проактивного інструментарію управління екологічними ризиками має актуальність та має практичні значення для сталого розвитку, як галузі, зокрема, так і для держави в цілому. У статтях пропонується авторські підходи до ідентифікації рівня екологічної складової авіаційного транспорту.*

Ключові слова: екологічна безпека; випереджаюче управління ризиками; сталий розвиток національної економіки; програма компенсацій та скорочення викидів діоксиду вуглецю для міжнародної авіації (CORSIA); ідентифікація рівня екологічної складової авіаційного транспорту.

Дмитрий. Бугайко, Юрий Харазишвили, Анна Антонова, Зэнон Замиар. "Идентификация уровня экологической составляющей авиационного транспорта с целью обеспечения устойчивого развития национальной экономики". *Безопасность авиационной отрасли является важной составляющей концепции общей национальной безопасности, системы обеспечения личной безопасности, экологической безопасности общества и безопасности на транспорте от внешних и внутренних угроз. Поддержание приемлемого уровня безопасности национальной авиации является приоритетной задачей отрасли. Особое значение в условиях глобализации приобретает экологическая безопасность. Международная организация гражданской авиации (ИКАО), учитывая динамические глобальные изменения климата, предлагает программу компенсаций и сокращения выбросов диоксида углерода для международной авиации (CORSIA). Основным инструментарием обеспечения этих задач является упреждающее управления рисками. Разработка проактивного инструментария управления экологическими рисками имеет актуальность и представляет практические значение для устойчивого развития, как отрасли, в частности, так и для* *государства в целом. В статье предлагаются авторские подходы к идентификации уровня экологической составляющей авиационного транспорта.*

Ключевые слова: экологическая безопасность; упреждающее управление рисками; устойчивое развитие национальной экономики; программа компенсаций и сокращения выбросов диоксида углерода для международной авиации (CORSIA); идентификация уровня экологической составляющей авиационного транспорта.

Introduction. Relevance and formulation of the problem. In September 2015, world leaders gathered at the United Nations (UN) and adopted the 2030 Agenda for Sustainable Development. It is a plan of action aimed at achieving global sustainable development in economic, social and environmental areas, which ensures that no UN member state is left behind.

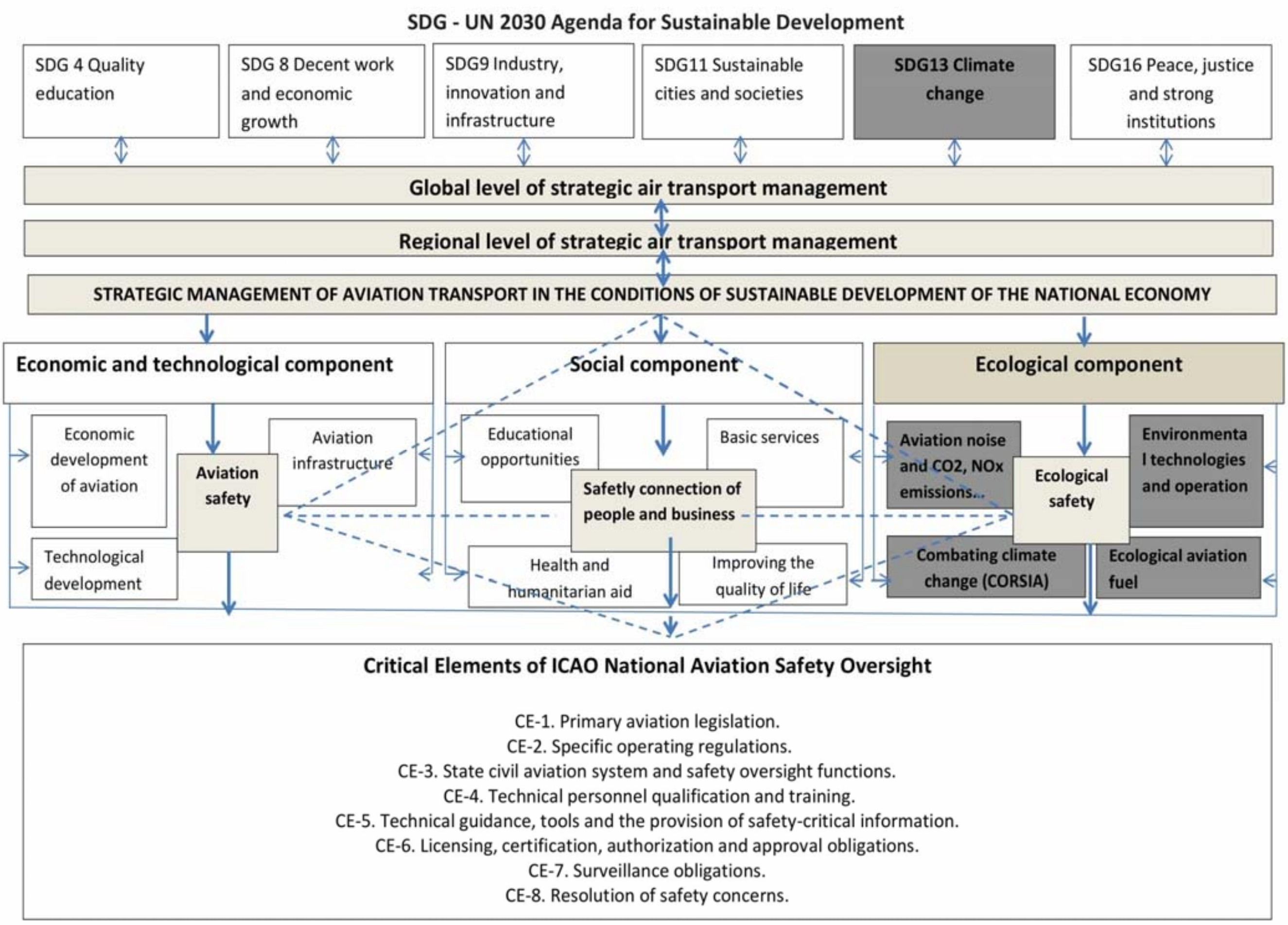

Figure 1 – Strategic management of aviation transport in the conditions of sustainable development of the national economy

Source: Bugayko D.O., Kharazishvili Yu.M. Theoretical bases of aviation branch strategic safety management in the context of maintenance of sustainable development of national economy. Bulletin of Economic Science of Ukraine. 2020. № 1 (38). Pp. 166-175. Institute of Industrial Economics of the National Academy of Sciences of Ukraine, Academy of Economic Sciences of Ukraine. doi: https://doi.org/10.37405/1729-7206.2020.1(38).166-175 10 [1].

The 17 sustainable development goals on the 2030 Agenda can be used as benchmarks for the coordinated development of UN member states.

The aviation industry is an open system that is affected by a wide range of ecological, technical, natural, human and economic hazards. For its part, it itself is a generator of

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significant threats to the environment. Therefore, we cannot imagine the aviation industry outside the search for answers to the latest global challenges. The main challenges for aviation are to develop air transportations at the national, regional and global levels, in order to ensure economic, social and environmental priorities.

Figure 1 shows a diagram "Strategic management of aviation transport in the conditions of sustainable development of the national economy".

Ecological safety is an important component of the concepts of general national security, the system of personal security, public safety and transport safety from external and internal threats. Maintaining an acceptable level of ecological safety at both the global and national levels is a priority.

The purpose of the article is to identify the level of the environmental component of air transport in order to develop effective tools for sustainable development of the national economy.

ICAO's Basket of Environmental Protection Measures. ICAO has identified the following areas that can contribute to the attainment of the global aspirational goals (Fig. 2):

– Aircraft related technology and standards;

– Improved air traffic management and operational improvements;

– Development and deployment of sustainable aviation fuel;

– The Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA)[2].

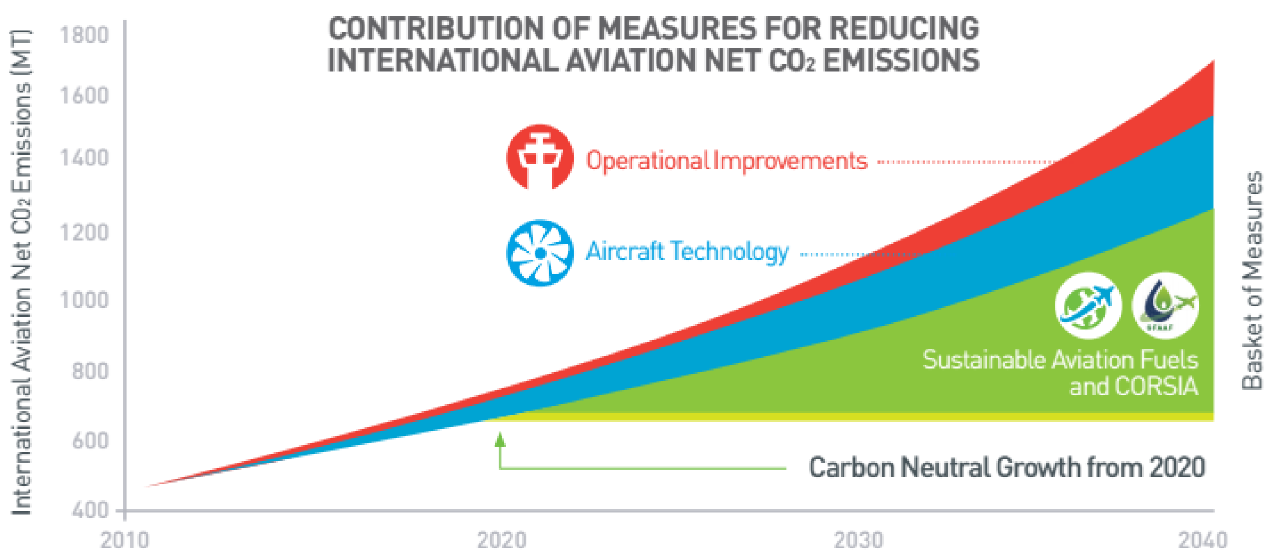

Figure 2 – Contribution of measures for reducing international aviation net CO2 emissions
Source: Carbon Offsetting And Reduction Scheme for International Aviation (CORSIA) implementation plan. ICAO, 2019 [2].

The Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA) the first global market-based measure for any sector and represents a cooperative approach that moves away from a "patchwork" of national or regional regulatory initiatives through the implementation of a global scheme that has been developed through global consensus among governments, industry, and international organizations. It offers a harmonized way to reduce emissions from international aviation ensuring that there is no market distortion, while respecting the special circumstances and respective capabilities of ICAO Member States [3].

ICAO Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA): History of Development. The

37th Session of the ICAO Assembly (2010) adopted two aspirational goals:

– to improve energy efficiency by 2 per cent per year until 2050, and

– to achieve carbon neutral growth from 2020 onwards.

Measures includes technological innovations, operational improvements, sustainable aviation fuels, and market based measures [3, 4].

The 38th Session of the ICAO Assembly (2013) decided to develop a global market-based measure for international aviation, further discussions on its design features and implementation mechanisms were undertaken, including possible means to address special circumstances and respective capabilities of States [3,5].

The 39th Session of the ICAO Assembly (2016). States finally adopted a global market-based measure scheme for international aviation, in the form of the Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA), to address the increase in total CO2 emissions from international aviation above the 2020 levels (Assembly Resolution A39-3) [3, 6].

The 40th Session of the ICAO Assembly (2019): acknowledges the progress achieved on all elements of the basket of measures available to address CO2 emissions from international aviation, including aircraft technologies, operational improvements, sustainable aviation fuels and CORSIA, and affirms the preference for the use of aircraft technologies, operational improvements and sustainable aviation fuels that provide the environmental benefits within the aviation sector. Marked that the environmental benefits from aircraft technologies, operational improvements and sustainable aviation fuels may not deliver sufficient CO2 emissions reductions to address the growth of international air traffic. Recalls its decision at the 39th Session to implement a GMBM scheme in the form of the Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA). Determines that the CORSIA is the only global market-based measure applying to CO2 emissions from international aviation so as to avoid a possible patchwork of duplicative State or regional MBMs [7].

Phased Implementation for the CORSIA. ICAO member states participating in CORSIA need to ensure that their airplane operators comply with the CORSIA offsetting requirements every three years, in addition to annual CO2 MRV [2].

Figure 3 – Phases of CORSIA implementation

Source: Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA) implementation plan. ICAO, 2019 [2].

The 39th and 40th Session of the ICAO Assembly introduced approach, which based on the use of a phased implementation for the CORSIA to accommodate the special circumstances and respective capabilities of States, in particular developing States, while minimizing market distortion, as follows:

Pilot phase applies from 2021 through 2023 to States that have volunteered to participate in the scheme.

First phase applies from 2024 through 2026 to States that voluntarily participate in the pilot phase, as well as any other States that volunteer to participate in this phase.

Second phase applies from 2027 through 2035 to all States that have an individual share of international aviation activities in RTKs in year 2018 above 0.5 per cent of total RTKs or whose cumulative share in the list of States from the highest to the lowest amount of RTKs reaches 90 per cent of total RTKs, except Least Developed Countries (LDCs), Small Island Developing States (SIDS) and Landlocked Developing Countries (LLDCs) unless they volunteer to participate in this phase.

Starting in 2022, the Council will conduct a review of the implementation of the CORSIA every three years, including its impact on the growth of international aviation, which serves as an important basis for the Council to consider whether it is necessary to make adjustments to the next phase or compliance cycle and, as appropriate, to recommend such adjustments to the Assembly for its decision [6, 7].

How to Calculate CO2 Offsetting Requirements?

Operator's annual emissions X Growth Factor = CO2 offsetting requirements [2]

The Growth Factor changes every year taking into account both the sectoral and the individual operator's emissions growth. The Growth Factor is the percent increase in the amount of emissions from the baseline to a given future year, and is calculated by ICAO (Fig. 4).

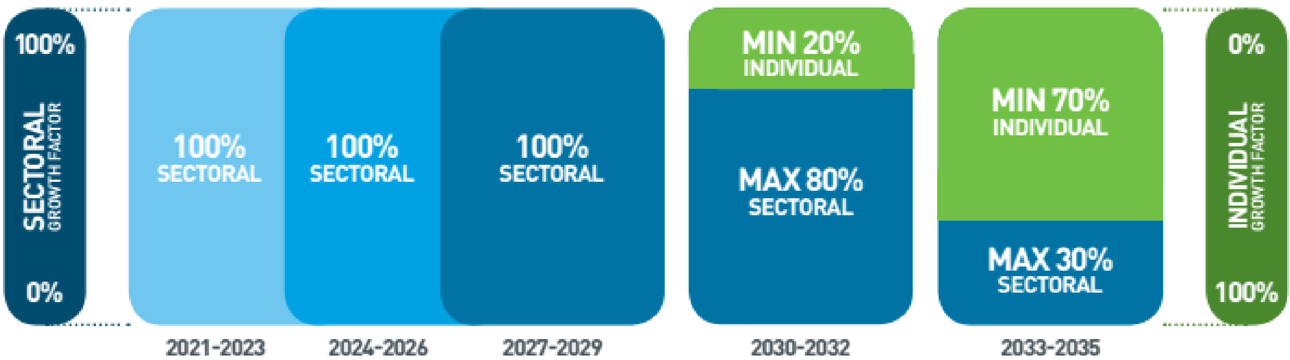

Figure 3 – Calculation CO2 offering requirements

Source: Carbon Offsetting And Reduction Scheme for International Aviation (CORSIA) implementation plan. ICAO, 2019 [2].

After the calculation of the offsetting requirements to be attributed to an aeroplane operator:

– The operator reports the use of CORSIA Eligible Fuels for the compliance period.

– The State deducts the benefits from the use of CORSIA Eligible Fuels and informs the operator's final offsetting requirements for the 3-year compliance period.

– The operator purchases and cancels eligible emissions units equivalent to its final offsetting requirements for the compliance period.

– The operator provides a validated Emissions Units Cancellation Report to the State, who checks the Report and informs ICAO [2].

How Does an Aeroplane Operator Monitor CO2 Emissions?

An aeroplane operator shall monitor and record its fuel use from international flights in accordance with an eligible monitoring method approved by the State to which it is attributed, and shall use the same eligible monitoring method for the entire 3-year compliance period.

An aeroplane operator can choose from five different eligible methods for fuel use monitoring. The methods are equivalent, there is no hierarchy for selecting a method.

An aeroplane operator may choose to use the ICAO CORSIA CO2 Estimation and Reporting Tool (CERT), accessible through the ICAO CORSIA website [2].

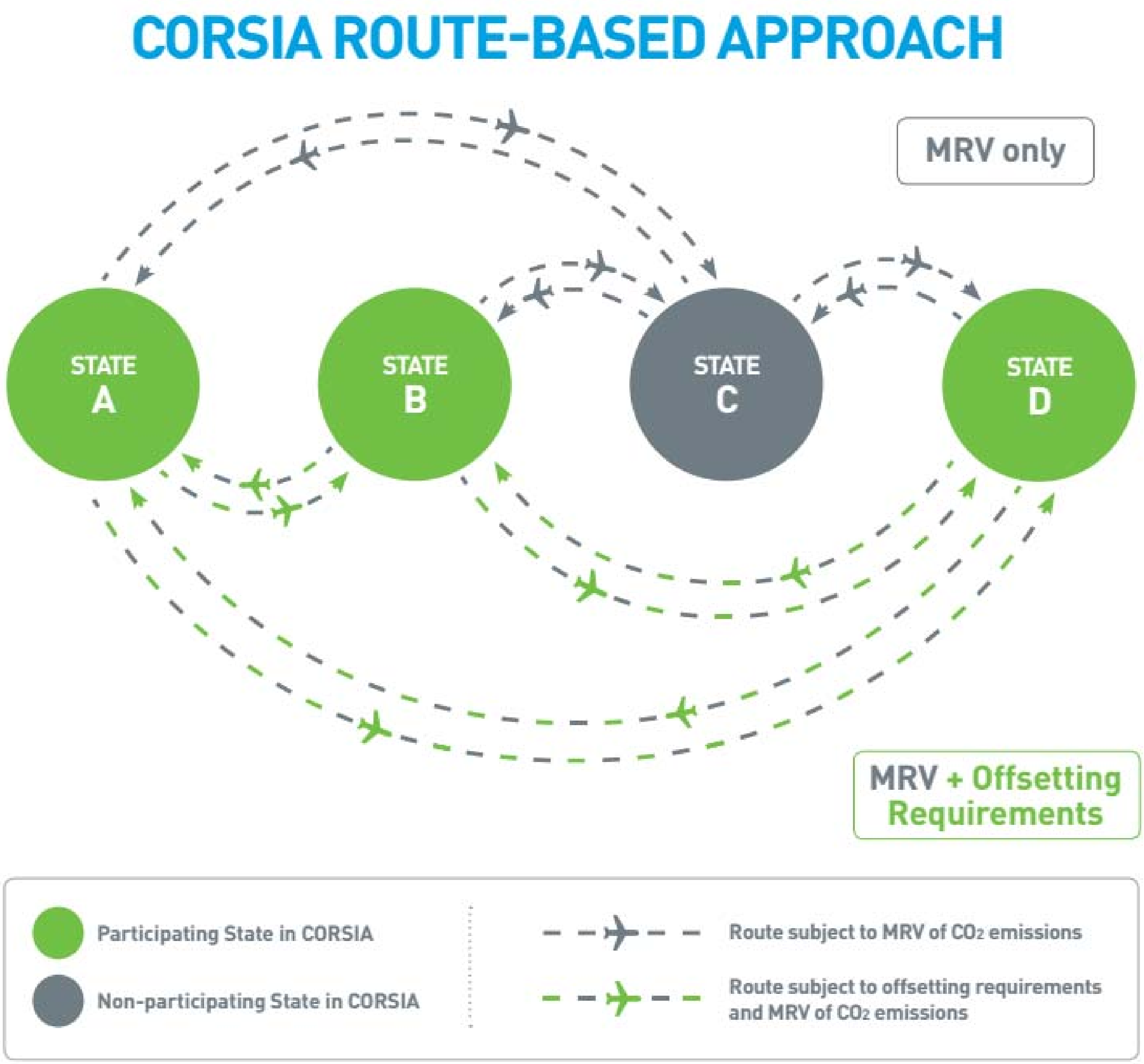

Figure 5 – CORSIA route-based approach

Source: Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA) implementation plan. ICAO, 2019 [2].

CORSIA Implementation. The success of the implementation of CORSIA relies on the establishment of a robust and transparent monitoring, reporting and verification (MRV) system, which includes procedures on how to monitor the fuel use, collect data and calculate CO2 emissions; report CO2 emissions data; and verify CO2 emissions data to ensure accuracy and avoid mistakes [4].

The implementation of CORSIA required a "package" of CORSIA-related SARPs and guidance which comprise of three distinct but interrelated components:

a) Annex 16, Volume IV, which provides the required actions by States and airplane operators (the "what" and "when") to implement CORSIA [3, 8];

b) Environmental Technical Manual (Doc 9501), Volume IV, which provides the guidance on the process (the "how") to implement CORSIA [3, 9]; and

c) Five CORSIA Implementation Elements, which are reflected in 14 ICAO documents and are approved by the Council prior to their publication [3].

These ICAO documents are directly referenced in Annex 16, Volume IV and are essential for the implementation of CORSIA. The Council adopted the First Edition of Annex 16. Volume IV in June 2018. Following its adoption, the First Edition of Annex 16, Volume IV became applicable on 1 January 2019. The First Edition of the Environmental Technical Manual (Doc 9501), Volume IV was issued under the authority of the ICAO Secretary General in August 2018. This manual will be periodically revised to make the most recent information available to administrating authorities, airplane operators, verification bodies and other interested parties in a timely manner, aiming at achieving the highest degree of harmonization possible.

The ICAO Council has been undertaking work, with the contribution of the CAEP, on the development of the five CORSIA Implementation Elements, namely:

– CORSIA States for Chapter 3 State Pairs is the list of States participating in CORSIA and will be used to define route-based emissions coverage every year from 2021 onwards;

– ICAO CORSIA CO2 Estimation and Reporting Tool (CERT) aims to simplify the estimation and reporting of CO2 emissions from international flights for those operators with low levels of activity to fulfil their monitoring and reporting requirements under CORSIA (for more details, see the dedicated article in this chapter);

– CORSIA Eligible Fuels cover aviation fuels used for the purposes of CORSIA to reduce the offsetting requirements of aeroplane operators (for more details, see the dedicated article in this chapter);

– CORSIA Eligible Emissions Units are emissions units from the carbon market that can be purchased by aeroplane operators to fulfill the offsetting requirements under CORSIA (for more details, see the dedicated article in this chapter); and

– CORSIA Central Registry (CCR) is an information management system that will allow the input and storage of CORSIA-relevant information reported by States, as well as calculations and reporting by ICAO, in accordance with the CORSIA MRV requirements as contained in the Annex 16, Volume IV (for more details, see the dedicated article in this chapter). In June 2018, to ensure that No Country is Left Behind, the Council endorsed the ICAO ACT-CORSIA (Assistance, Capacity-building and Training for the CORSIA) Programme, emphasizing the importance of a coordinated approach under ICAO to harmonize and bring together all relevant actions and promote coherence to capacity building efforts related to CORSIA implementation. By the end of June 2019, CORSIA buddy partnerships under ACT-CORSIA had been established, involving 15 donor States and 98 recipient States [3].

CORSIA Emissions Unit Eligibility Criteria. Program Design Elements. At the program level, ICAO should ensure that eligible offset credit programs meet the following design elements:

1. Clear Methodologies and Protocols, and their Development Process.

2. Scope Considerations.

3. Offset Credit Issuance and Retirement Procedures.

4. Identification and Tracking.

5. Legal Nature and Transfer of Units.

6. Validation and Verification procedures.

7. Program Governance.

8. Transparency and Public Participation Provisions.

9. Safeguards System.

10. Sustainable Development Criteria.

11. Avoidance of Double Counting, Issuance and Claiming.

Carbon Offset Credit Integrity Assessment Criteria: There are a number of generally agreed principles that have been broadly applied across both regulatory and voluntary offset credit programs to address environmental and social integrity. Eligibility criteria should apply at the program level, as the expertise and resources needed to develop and implement ICAO emissions criteria at a methodology and project level is likely to be considerable.

Eligibility Criterion: Carbon offset programs must generate units that represent emissions reductions, avoidance, or removals that are additional.

1. Eligibility Criterion: Carbon offset programs must generate units that represent emissions reductions, avoidance, or removals that are additional.

2. Eligibility Criterion: Carbon offset credits must be based on a realistic and credible baseline.

3. Eligibility Criterion: Carbon offset credits must be quantified, monitored, reported and verified.

4. Eligibility Criterion: Carbon offset credits must have a clear and transparent chain of custody within the offset program.

5. Eligibility Criterion: Permanence.

6. Eligibility Criterion: A system must have measures in place to assess and mitigate incidences of material leakage.

7. Eligibility Criterion: Are only counted once towards a mitigation obligation.

8. Eligibility Criterion: Carbon offset credits must represent emissions reductions, avoidance, or carbon sequestration from projects that do no net harm [8].

ICAO CORSIA Package. The 'CORSIA Package' contains various elements that are all critical to the successful implementation of CORSIA. They include:

a) Annex 16 Volume IV – Standard and Recommend Practices (SARPs) [8];

b) Environmental Technical Manual (ETM) Volume IV – Guidance Material [9];

c) ICAO CORSIA Supporting Information; and

d) Supporting Documents – Technical Information and ICAO Processes to maintain the Supporting Information.

The Annex 16 Volume IV and ETM Volume IV follow a similar structure to that of the other Annex 16 Volumes (Figure 6). This includes Chapters containing requirements on administration, MRV, CO2 offsetting requirements, Sustainable Aviation Fuels and eligible Emissions Units. Additional detailed processes and information within the Appendices supplement these requirements. The Annex 16 Volume IV also has Attachments that provide supporting information on the implementation of the standard and recommended practices.

The CORSIA also raises various innovative issues, such as:

– the definition of roles and responsibilities of the ICAO Secretariat;

– information required for the implementation of CORSIA and

– information that will need to be updated more often than the typical three-year approval cycle of Annex 16 Volumes. In order to address these issues, it is proposed to develop and use 'ICAO CORSIA Supporting Information' that is expected to be captured in some form of ICAO documentation (e.g., ICAO Document, Council Decision), managed and approved by an ICAO Body and finally published by ICAO such that it is available to the public. This information is directly referenced in Annex 16 Volume IV, and is therefore considered to be an integral part of Standard and Recommend Practices.

The content of the ICAO CORSIA Supporting Information will be built upon the relevant Supporting Documents. The Supporting Documents will include technical information and ICAO processes that will serve as the basis for managing and approving the Supporting Information. Thus the roles of ICAO in the implementation of CORSIA, which cannot be placed directly in Annex 16 Volume IV, can be clearly defined [11].

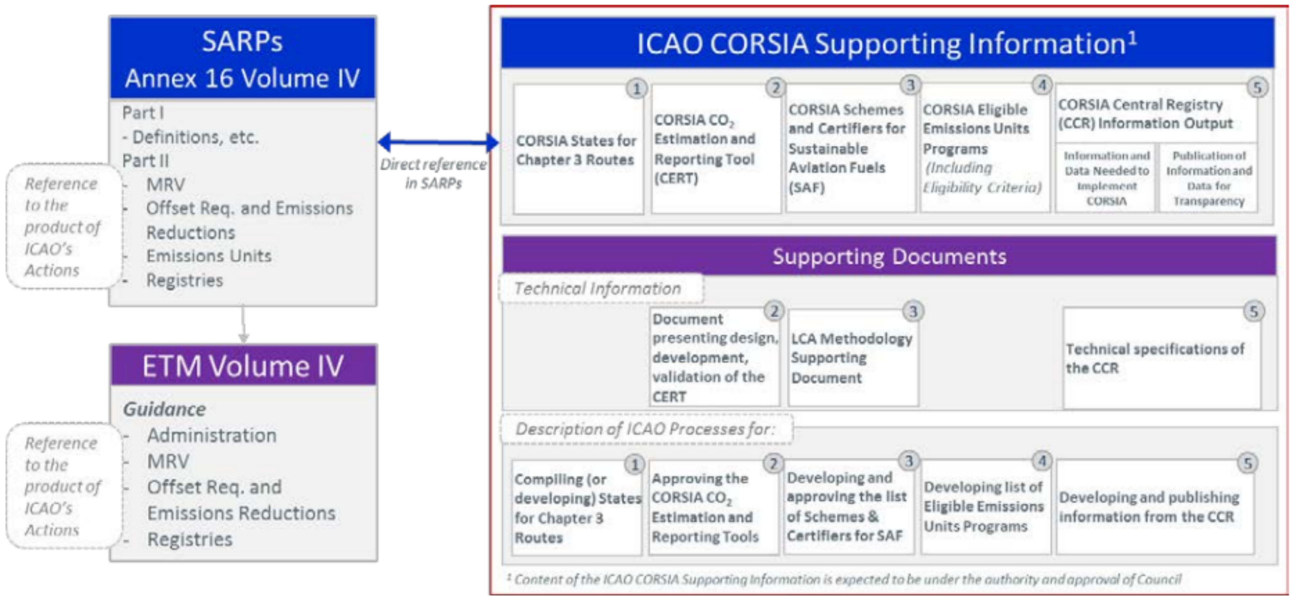

Figure 6 – Overview of the CORSIA Package containing various elements including the Annex 16 Volume IV (SARPs), ETM, ICAO CORSIA Supporting Information and Supporting Documents

Source: Committee On Aviation Environmental Protection (CAEP) Steering Group Meeting Montréal, Canada, 11 to 15 September 2017. Agenda Item 3: Global Market Based Measure Technical (GMTF) ICAO/ CORSIA PACKAGE (Presented by GMTF co-Rapporteurs), ICAO, 2019 [11].

Identification of Ukrainian Air Transport Ecological Component Level. Statistics on the activities of the aviation industry of Ukraine (2010 – 2019) indicate its stable development. During 2019, passenger and cargo transportation was performed by 29 domestic airlines, which performed a total of 103.3 thousand commercial flights (in 2018 - 100.2 thousand flights). The main production indicators of passenger air transportation are given in Table1 and 2 [12].

Table 1.

Air transportation of passengers and passenger turnover of Ukraine

	2010	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**
Million passengers	6	6	6	8	9	12	13,6
Passenger turnover (billion passenger-kilometers (RPK))	11	11,6	11,4	15,5	20,4	25,9	30,058

Source: State Statistics Service of Ukraine Edited by I. Petrenko. Transport and Communications of Ukraine 2018. Statistical collection. ISBN 978-617-7551-10-1 State Statistics Service of Ukraine, Kyiv - 2019 - 154 p.

In 2019 year, the market of passenger air transportation continued to show positive dynamics. According to statistics on the number of passengers who used the services of Ukrainian enterprises, increased by 9.4 percent and amounted to 13705.8 thousand passengers. During the year, passenger traffic operated in 18 domestic air directions. During 2019 year a total of 13,306.7 thousand people were transported [12].

Table 2.

Transportation of passengers by air by type of service

(Thousands of passengers)

	2010	2014	2015	2016	2017	2018	2019
Total	6 106,5	6 473,3	6 302,7	8 277,9	10 555,6	12 529,0	13 705,2
International	5 144,3	5 826,7	5 678,0	7 475,4	9 614,5	11 446,1	12 547,2
Domestic	962,2	646,6	624,7	802,5	941,1	1 082,9	1 158

Source: State Statistics Service of Ukraine Edited by I. Petrenko. Transport and Communications of Ukraine 2018. Statistical collection. ISBN 978-617-7551-10-1 State Statistics Service of Ukraine, Kyiv - 2019 - 154 p.

The Ministry of Infrastructure of Ukraine conducted a forecast of the volume of air passenger traffic in the Ukrainian national segment. The results of the forecast are shown in Figure7.

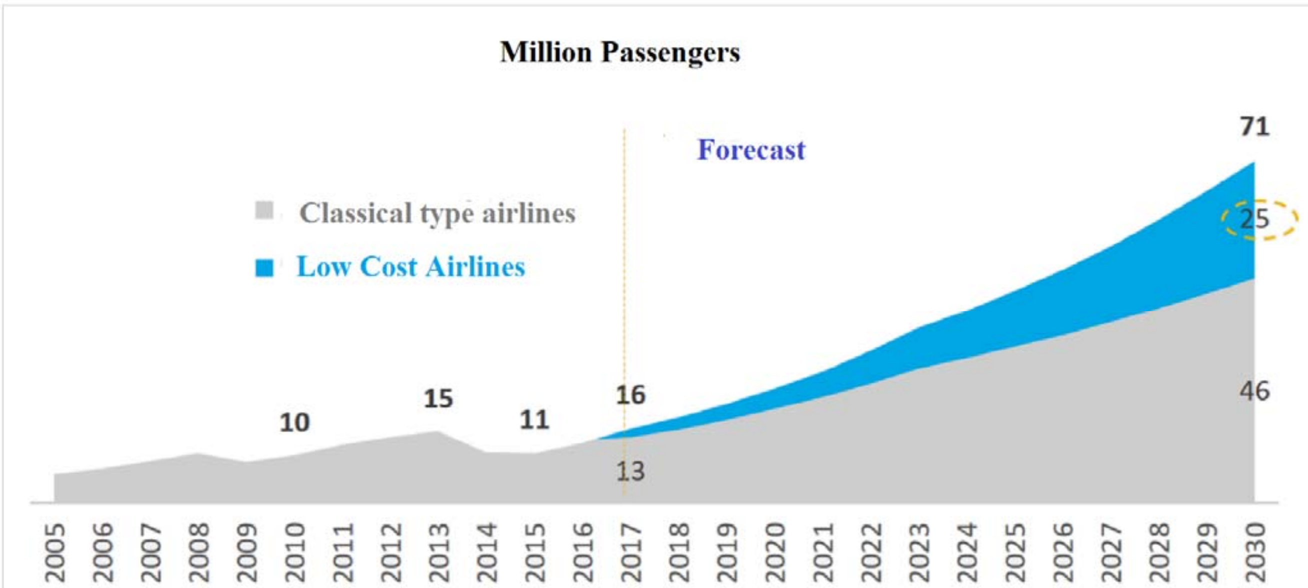

Figure 7 – Air Passenger Traffic Forecast (2018 - 2030) of Ministry of Infrastructure of Ukraine
Source: Official site of Ministry of Infrastructure of Ukraine: https://mtu.gov.ua/files/lowcost.pdf

Passenger traffic through the airports of Ukraine by 2030 will increase 4.3 times compared to 2017 - to 71.2 million out of 16.5 million people. Such forecasts have been provided by the Cabinet of Ministers. In addition, by 2030, the share of passenger traffic carried by low-cost airlines is expected to increase to 35% of the total, as well as the reduction of the minimum ticket price to 25-30 euros. In particular, the Ministry of Infrastructure hopes to triple the network of domestic routes, international – to double, and attract air transit cargo through the capital and regional airports of Ukraine. Therefore, the results of the forecast are quite optimistic. However, both globally and nationally in 2020, we are experiencing the negative impact of the COVID 19 pandemic factor, which leads to unpredictable consequences. To corrections of optimistic forecasts of global and national aviation will be devoted to our next scientific works [12].

However, unfortunately, the dynamic growth of air traffic entails an increase in emissions of chemical elements into the atmosphere, which are a real threat to the environment and can contribute to climate change processes. To model the level of ecological safety of air transport, a set of indicators was selected, based on the availability of sources of reliable information to form a sufficient set of data for calculations:

1. The level of CO2 emissions from air transport to the created the Gross Value Added (GVA), kg / USD. USA (D / de-stimulator)).

2. The level of emissions of air transport pollutants into the atmosphere to the created the Gross Value Added (GVA), kg / dollar. USA (D).

3. The level of environmental costs of air transport before release, % (S / stimulator)).

The first two indicators are de-stimulators, are calculated in relation to the Gross Value Added (GVA) of air transport and characterize the level of negative environmental impact in the conversion of energy resources into services. From the point of view of the system approach these indicators reflect the procedurally of the system. Their dynamics is determined according to the State Statistics Service of Ukraine, and for comparison with other countries the data of the International Energy Agency are used.

The following indicator is a stimulator. It characterizes the costs incurred for the maintenance (maintenance and operation) of the object (fixed assets for environmental purposes) in working condition, and is part of the costs of the current period. Indicator calculated by the ratio of costs to the production of air transport in percent. As the State Statistics Service of Ukraine does not publish such data for air transport, the current environmental protection costs for air transport are calculated in proportion to similar costs and transport and communications in general.

To solve the problem of integrated assessment of the level of environmental safety of air transport in Ukraine, a universal methodology of identification and strategy in the field of national security is used, which allows to compare indicators of different security areas and substantiate strategic scenarios of security development [13, p. 41].

The safe measurement of the ecological component of air transport involves the definition of the boundaries of safe existence and the identification of the level of ecological development in comparison with the threshold values. Determining the limits of safe existence of a dynamic system is based on applied systems theory [14], the concept of "homeostatic plateau" and the method of "t-test", which allows to obtain a vector of threshold values of each indicator: lower and upper critical (red zone), lower and upper threshold (orange zone), lower and upper optimal (green zone).

Table 3.

Formalized Threshold Vector Values*

Type of functions of density of probabilities of indicators	Lower threshold value	Lower optimal value	Upper optimal value	Upper threshold value
Normal	$\mu - t \times \sigma$	$\mu - \sigma$	$\mu + \sigma$	$\mu + t \times \sigma$
Lognormal	$\mu - t \times \frac{\sigma}{k_{as}}$	$\mu - \frac{\sigma}{k_{as}}$	$\mu + \sigma$	$\mu + t \times \sigma$
Exponential	$\mu - \frac{\sigma}{k_{as}}$	μ	$\mu + \sigma$	$\mu + t \times \sigma$

Source: Turner, J.C. (1972) Modern Applied Mathematics: Probability, Statistics, Operational Research. New York: Van Nostrand Reinhold

* *For critical values, instead of t,* $\pm 3\sigma$ *or more is used for abbreviated samples*

According to the results of the analysis of indicator values by the "t-criterion" method, three characteristic types of distribution of probability density functions were revealed [13, p. 70-72]: normal, lognormal and exponential, for which a formalized definition of the vector of threshold values is proposed, where is the mean value, is the standard deviation, t is taken from the Student's t-distribution tables [15] (Table 3).

Identification of the level of the ecological component of air transport in the safety dimension uses the multiplicative form of the integrated index.

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

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

modified rationing method

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

where *x* – value of the indicator; $k_{норм}$ - normalization coefficient (for stimulators it is equal to the maximum value from a number of indicators and threshold values; for destimulators it is chosen higher than the maximum value from the same series by 5–10%);

and dynamic weights due to a combination of methods of "main components" and "sliding matrix" [13, p. 66-81], which requires in the next shift of the matrices of the minimum required size over a period of time and the determination of weights for the current time period of the main components. The minimum required size of the matrices is determined under the condition of equality of the number of indicators (the number of main components) and the number of positive eigenvalues of this matrix:

$$C_i \times D_i = \begin{pmatrix} d_1 c_{11} + d_2 c_{12} + \ldots + d_j c_{1j} \\ d_1 c_{21} + d_2 c_{22} + \ldots + d_j c_{2j} \\ \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \\ d_1 c_{j1} + d_2 c_{j2} + \ldots + d_j c_{jj} \end{pmatrix} = \begin{pmatrix} w_1 \\ w_2 \\ \ldots \\ w_j \end{pmatrix}, \quad a_i = \frac{w_i}{\sum w_i}, \tag{3}$$

where *C* – the matrix of absolute values of factor loads; *D* – the vector-matrix of variances.

The result of the application of this methodology is the dynamics of the integrated index of environmental safety of air transport (Figure 8).

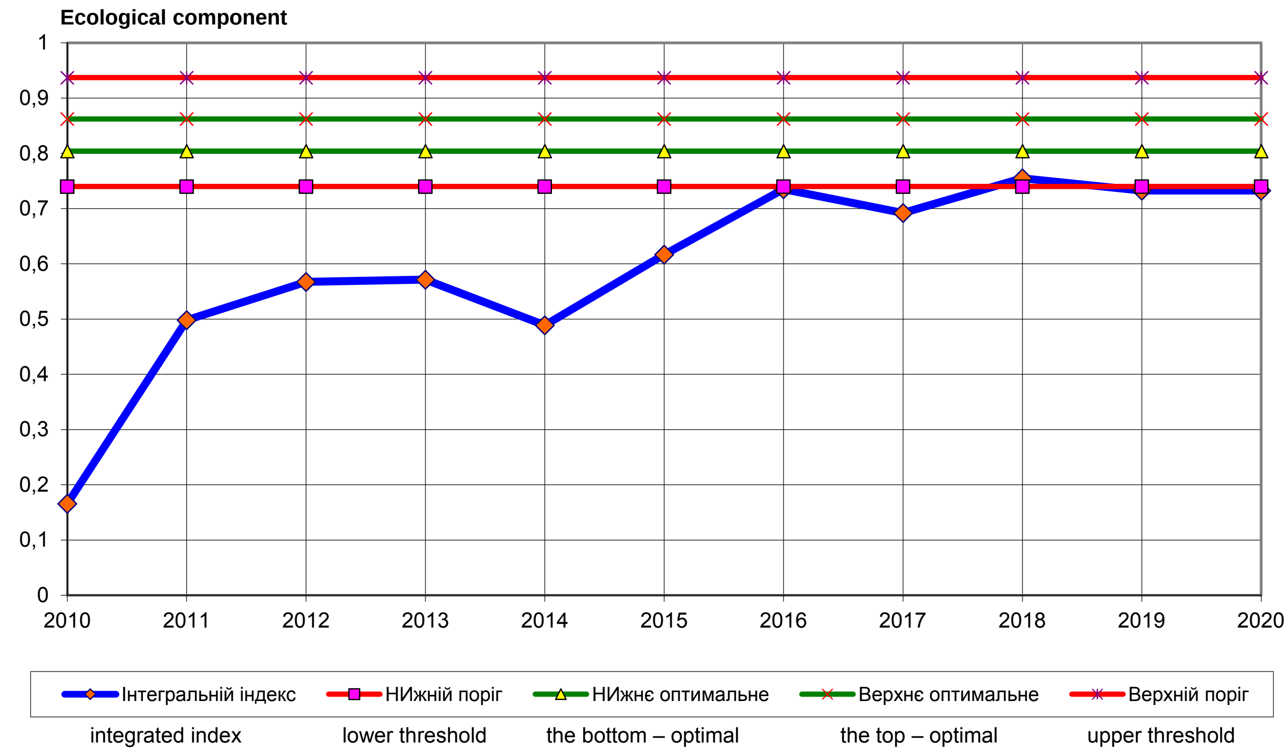

Figure 8 – Dynamics of the integrated index of air transport ecological component in the safety dimension.

The dynamics of the integrated index of air transport ecological component shows positive dynamics, but does not reach the optimal zone, where there is negative feedback and the best conditions for the functioning of the system. Given that the criterion of sustainable development is the average optimal value of the vector of threshold values [13], it is possible to calculate the deviation of integrated indices from the criteria of sustainable development, which indicates the disproportion of their development (Figure 9) and determines the list of important threats.

Equalizing disproportion and zeroing deviations in the future will ensure balanced sustainable development. The task of regulation is to ensure that the integral indices are in the optimal zone.

Conclusions. The ecological safety of the state is an integral characteristic of a set of interconnected structural components. In turn, national ecological safety is a subsystem of the highest level systems – regional ecological safety and global ecological safety. This confirms the complexity and versatility of the concept of " ecological safety ". In the context of globalization, ecological safety is becoming especially important. In view of the dynamic global climate change, the International Civil Aviation Organization (ICAO) is proposing an initiative Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA).

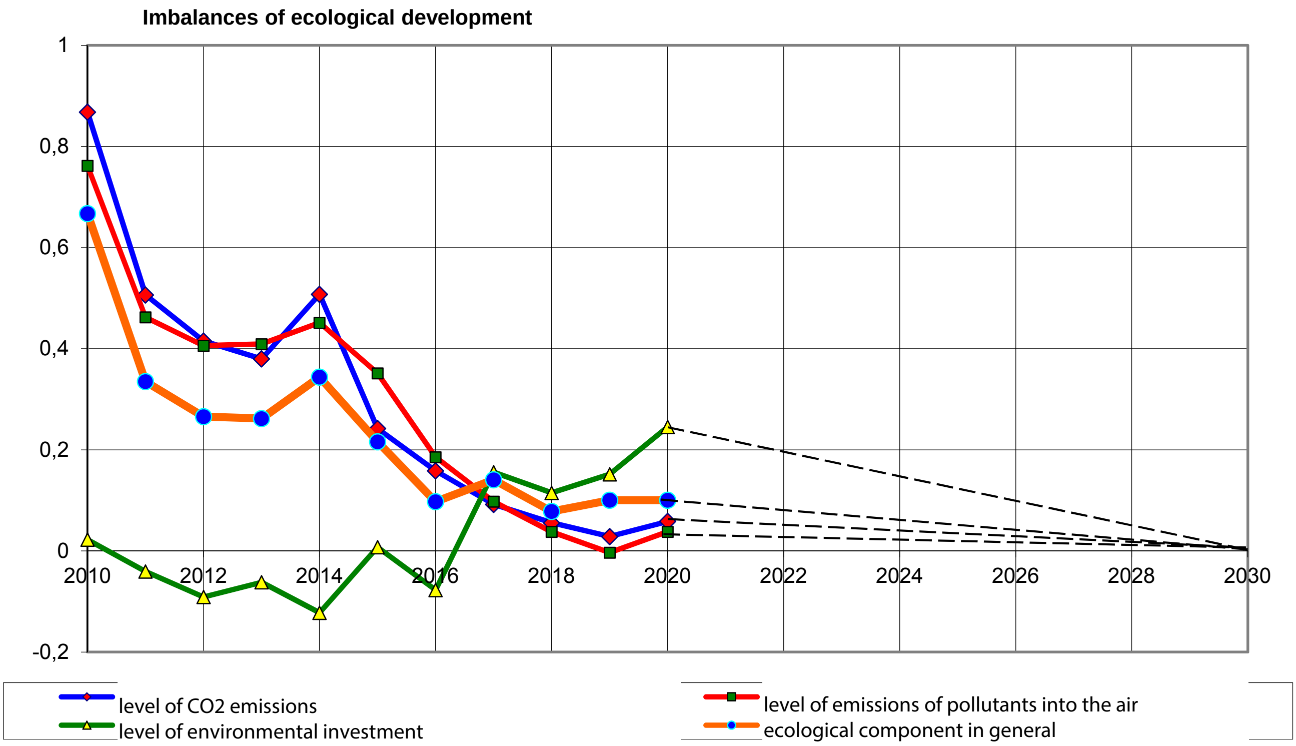

Figure 9 – Imbalances of ecological development of air transport

The main tool of ecological safety is proactive risk management. The development of proactive tools for ecological risk management is relevant and has practical implications for sustainable development, both in the industry in particular and for the state as a whole. The articles offer the author's approaches to the identification of air transport ecological component level. The dynamics of the integrated index of air transport ecological component in period from 2010 till 2020 years shows positive dynamics, but does not reach the optimal zone, where there is negative feedback and the best conditions for the functioning of the system. Given that the criterion of sustainable development is the average optimal value of the vector of threshold values, it is possible to calculate the deviation of integrated indices from the criteria of sustainable development, which indicates the disproportion of their development and determines the list of important threats.

Thus, proactive ecological risk management is the key to maintaining the reliability and sustainable development of the national economy in the context of the preservation of the global ecological system.

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