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STRATEGIC SCENARIOS OF THE POST-WAR RECOVERY OF THE AVIATION TRANSPORT SUSTAINABLE DEVELOPMENT: THE CASE OF UKRAINE

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Abstract. The state and strategic scenarios to recover the sustainable development of air transport in Ukraine in the post-war period are studied. Research is fulfilled with the scientific justification of quantitative indicators and macro-indicators of maintaining the trajectory of sustainable development in the medium-term perspective. The starting point of strategizing is the concept of sustainable development in the safety dimension as a management construct that contains a general systemic view of the ways to transfer from the current state of the management object to the desired one and includes the stages of identification and strategizing. Identification involves an integral convolution with dynamic weighting coefficients and a formalized justification of the limits of safe existence. A new methodology is used for strategizing, which, unlike classical forecasting methods (the past determines the future), uses the principle "the future is determined by the trajectory into the future" and is based on the method of adaptive regulation from the management theory. According to the defined methodology, three strategic recovery scenarios were developed with the annual rates of growth of real aviation transport: realistic – 4.5%; optimistic – 7.2% and the scenario of entering the optimal zone of the EU countries – 10.4%. The resulting dynamics of components, indicators and macro indicators is, in fact, a strategic plan for the post-war recovery of the economy and entering the path of sustainable development. Threats are identified and institutional measures are proposed for airlines and national systems of airports and airfields, air navigation services, aviation industry, aviation education and science of Ukraine. The strategic orientations of the environmentalization of air transport of Ukraine in the post-war period and the strategic priorities of the recovery of the air transport infrastructure were formulated, and the necessity to pursue a course towards carbon neutrality was proved.

Keywords: aviation transport, sustainable development, security dimension, strategic management, environmental strategy

JEL Classification: C18, C61, Q01

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1. Introduction

Aviation transport is an open system influenced by many factors: social (Arefieva et al., 2021; Kharazishvili et al., 2020), economic (Coban et al., 2022a), ecological (Chygryn et al., 2020), financial (Moskalenko et al., 2022; Miśkiewicz et al., 2022), government (Nawawi et al, 2022; Miskiewicz, 2022), and technological (Vaníčková & Szczepańska-Woszczyna, 2020), both related and unrelated. In many countries, aviation plays a crucial role in facilitating economic development, inclusive growth, and international trade. However, the aviation industry is also one of the largest emitters of greenhouse gases, contributing to global warming and climate change (Polcyn, 2022). This has led to growing concerns about the sustainability of aviation and its long-term impact on the environment. To address these challenges, aviation stakeholders are increasingly focusing on innovative solutions that can help reduce the industry's environmental footprint while supporting economic growth and social development (Borodin et al., 2021). In addition to investing in new technologies, aviation stakeholders are also exploring ways to improve air traffic management systems, reduce waste and carbon emissions, and promote more sustainable practices throughout the industry (Miśkiewicz 2021a; Coban et al., 2022b; Miskiewicz, 2022). Collaboration between all stakeholders is key to ensuring that aviation transport supports sustainable development in a balanced and inclusive direction (Oláh et al., 2021).

The full-scale military aggression of the Russian Federation against Ukraine from the first minute dealt a devastating blow to the activity of the aviation transport of Ukraine as a whole and the activity of all its components: airlines, airport and airfield systems, air traffic control systems, aviation industry systems of Ukraine, aviation systems education and science. The industry faced unforeseen force majeure challenges and threats to its existence. Under such conditions, the development and substantiation of strategic scenarios for the sustainable development of air transport in Ukraine in the conditions of the post-war economic recovery acquire undeniable relevance and is of practical importance for the further development of both air transport and the national economy, as a whole.

2. The Study Area

Developing strategic scenarios for a country's sustainable development is crucial to achieving long-term sustainability goals (Yang et al., 2021; Banasik et al., 2022). The outputs of the studies (Wróblewski et al., 2018; Kuzior et al., 2021a; Kwilinski et al., 2022b) show that strategic scenarios help to identify potential challenges and opportunities for sustainable development and provide a framework for decision-making that considers multiple factors, including environmental, social, and economic considerations. Dzwigol et al. (2020a) and Drożdż et al. (2021) note that strategic scenarios help policymakers and other stakeholders to identify critical areas of focus for sustainable development, such as improving access to clean energy, reducing greenhouse gas emissions, and promoting sustainable land-use practices. According to Dementyev and Kwilinski (2020) and Dementyev et al. (2021), by analyzing various scenarios, decision-makers can evaluate the potential impact of different policy

interventions and determine the best course of action to achieve sustainable development goals.

In the studies (Kwilinski, 2019; Bogachov et al., 2020; Cyfert et al., 2021; Chen et al., 2021), the authors analysed post-war recovery efforts in several conflict-affected countries and identified the need for a strategic approach to sustainable development that considers the long-term impacts of reconstruction and development programs. They found that a lack of coordination between different actors and limited resources often led to ineffective recovery efforts that did not address underlying structural issues or promote sustainable development. Similarly, in the studies (Miśkiewicz 2019; Lyulyov et al. 2021a; Miśkiewicz, 2021a; Saługa et al., 2021), the authors examined the impact of post-war recovery efforts on environmental sustainability. They found that while reconstruction and development programs had led to economic growth and improved social conditions, they had also contributed to environmental degradation and the displacement of indigenous communities. The studies (Dzwigol et al, 2019; Dzwigol, 2020; Dzwigol & Dzwigol-Barosz, 2020; Dzwigol et al, 2020b; Dzwigol, 2021) have emphasized the need for a strategic approach to sustainable development that considers the long-term impacts of recovery efforts on social, economic, and environmental factors. For example, in a study by Dzwigol et al. (2020b), the authors developed a strategic scenario analysis framework to identify key areas of focus for sustainable development in post-conflict regions. They found that this approach could help to ensure that recovery efforts were inclusive, equitable, and sustainable over the long term. Moreover, studies (Kwilinski, 2018; Miśkiewicz, 2018; Shafait et al., 2021; Abazov, 2021; Kuzior et al., 2022) have highlighted the importance of incorporating environmental, educational, and social considerations into post-war recovery.

Considering the continuation of the military actions of the russian federation (RF) against Ukraine, forecasts of the economic decline are crucial for understanding the current state and developing strategic scenarios for its recovery. Even after five months of the RF's war against Ukraine, forecast estimates of foreign and domestic experts regarding the world's economies, the RF, and Ukraine appeared, ranging from -20% to -45%. All forecasts of Ukraine's development today are highly speculative, even taken from the ceiling (Ash, 2022). Still, they are needed to understand the approximate depth of the fall and to substantiate the indicators and macro-indicators of the future economic policy of restoring the post-war economy of Ukraine. The main proposals declare the principles of economic recovery. Still, they are needed to understand the approximate depth of the fall and to substantiate the indicators and macro-indicators of the future economic policy of restoring the post-war economy of Ukraine. The main proposals declare the principles of economic recovery. In the studies (International Civil Aviation Organization, 2017; Frenkel, 2017; Tkachenko et al., 2019; Kim et al., 2019; Ellis, 2020), the authors elaborate on the main strategic planning tool, SWOT analysis, based on the current state of the aviation industry, studying its ecosystem, expert, and passenger surveys to identify strengths and weaknesses, opportunities and threats. Pereira et al. (2022), regarding the comprehensive evaluation of the impact of military operations, run on the territory of Ukraine on the ecological state, is also known.

An unresolved part of research is the development of a strategy for the sustainable development of aviation transport of Ukraine in the post-war conditions, as a country that has a full cycle of development, production and operation of aviation equipment, as well as an extensive system of training and retraining of aviation personnel. Therefore, the purpose of the article is to develop strategic scenarios for the post-war recovery of air transport in Ukraine with scientific justification of quantitative indicators and macro-indicators of maintaining the trajectory of sustainable development in the medium-term perspective.

3. Materials and Methods

The starting point for devising strategic scenarios for the post-war restoration of aviation transport is the concept of sustainable development in the safety dimension as a management structure containing a general systemic view of the ways to transfer from the current state of the management object to the desired one (Kharazishvili et al., 2021) and includes the stages of identification and strategizing. Identification of the current state of sustainable development in the safety dimension is a necessary stage and includes determining the structure of the research object, forming a system of indicators, choosing the form of an integral index (multiplicative) (Dementyev et al., 2021; Kharazishvili et al., 2021a; Kharazishvili et al., 2021b):

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

where $z_{i,t}$ stands for normalized values of indicators; a_i means dynamic weighting coefficients; I is a serial number of the indicator; t is a time period;

Selection of the rationing method (Hussain et al., 2021; Kuzior et al., 2021b):
for stimulants:

$$z_{i,t} = \frac{x_i}{k_{n,t}}, \tag{2}$$

for inhibitors:

$$z_{i,t} = \frac{(k_{n,t} - x_i)}{k_{n,t}};\ \ k_{n,t} \geq x_{\max,t}, \tag{3}$$

where $k_{n,t}$ – a normalization factor;

Scientific substantiation of dynamic weighting factors: based on a combination of the "Principal Components" and "Sliding Matrix" methods (Kwilinski et al., 2020b; Kwilinski et al., 2022a; Kuzior et al., 2021b), which consists in successively shifting the matrix of the minimum required size over a period of time and calculating the weighting factors;

Scientific substantiation of the limits of safe existence – the vector of limit values is closely related to the concept of "extended homeostatic plateau," which has optimal (negative feedback), threshold (neutral feedback) and critical (positive feedback) spheres, which determines safety gradations on both sides of the "homeostatic plateau:" lower and upper critical, threshold and optimal, for which formulas for calculating the vector of limit values are proposed (Table 1):

Table 1. Formalized threshold vector values

TIPDF	LT	LOV	UOV	UT
Normal	$\mu - t \times \sigma$	$\mu - \sigma$	$\mu + \sigma$	$\mu + t \times \sigma$
Lognormal (tail right)	$\mu - t \times \sigma / k_{as}$	$\mu - \sigma / k_{as}$	$\mu + \sigma$	$\mu + t \times \sigma$
Lognormal (tail left)	$\mu - t \times \sigma$	$\mu - \sigma$	$\mu + \sigma / k_{as}$	$\mu + t \times \sigma / k_{as}$
Exponential (tail right)	$\mu - \sigma / k_{as}$	μ	$\mu + \sigma$	$\mu + t \times \sigma$
Exponential (tail left)	$\mu - t \times \sigma$	$\mu - \sigma$	μ	$\mu + \sigma / k_{as}$

Note: TIPDF – Type of Indicator Probability Density Function; LT – Lower Threshold; LOV – Lower Optimal Value; UOV – Upper Optimal Value; UT – Upper Threshold
Source: (Kharazishvili et al., 2021).

The simultaneous integral convolution of indicators and their limit values makes it possible to change the level of sustainable development in the security dimension. The structure of sustainable development of air transport is presented in Figure 1 and is described by 29 indicators, 7 of which are shadow indicators for model calculations (Kharazishvili, 2017). Moreover, each indicator is assigned to stimulators (S, the increase of which is desirable) or to de-stimulators (D), the decrease of which is desirable.

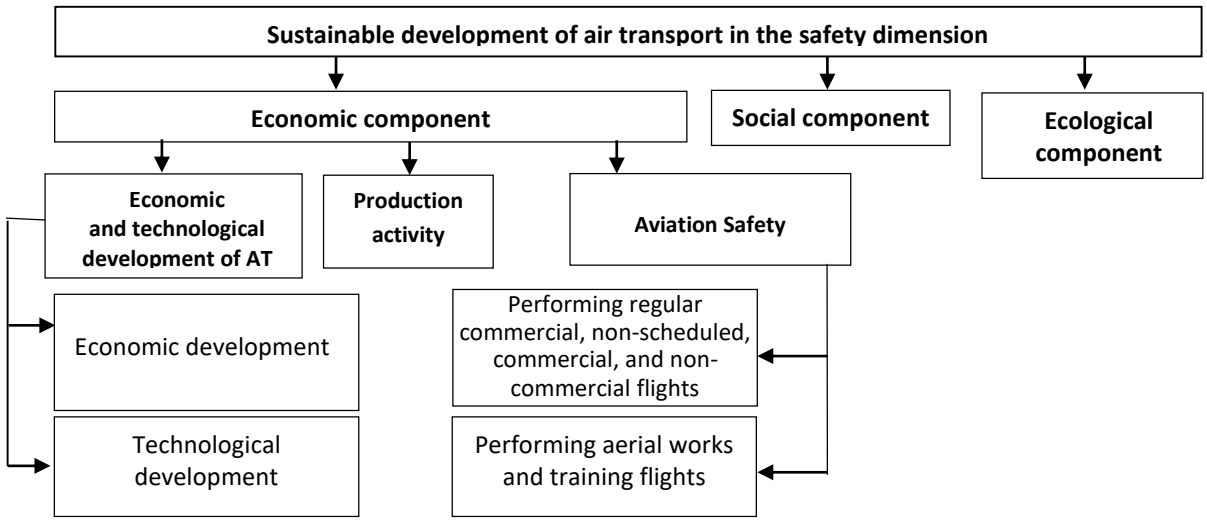

Figure 1. A Hierarchical Structure of Components of the Air Transport Sustainable Development
Source: designed by the authors.

To develop strategic scenarios for the post-war recovery of air transport, a new principle of strategizing "the future is determined by the trajectory into the future" is used, which consists in identifying the level of sustainable development in the security dimension, defining strategic goals, building the future trajectory of the desired development, solving the inverse problem of synthesizing the necessary values of components and indicators through the sequential decomposition of integral indices using adaptive control methods from the management theory (Drozdz et al., 2020b; Dzwigol, 2021; Dzwigol-Barosz & Dzwigol, 2021; Kharazishvili et al., 2021; Trzeciak et al., 2022) (Figure 2).

In the "Identification" block, integral convolution equations of type (1) for the components of sustainable development of air transport are set sequentially, and in the "reference model" the desired values of the future integral index are set. Therefore, the control device evaluating the error changes the value of the indicators in such a way as to reduce it to zero taking into account the limitations.

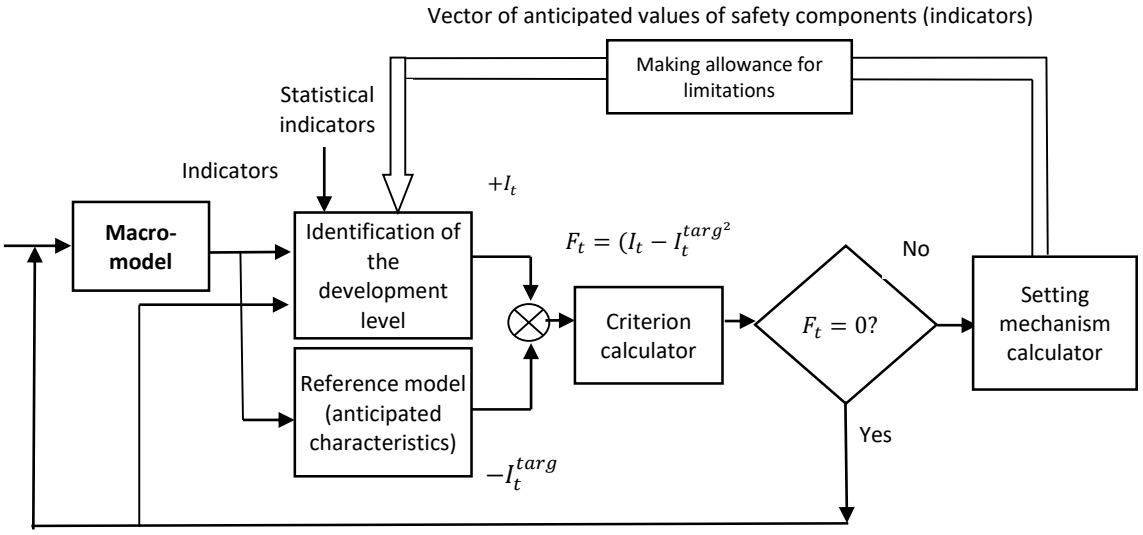

Figure 2. A Generalized Scheme of an Adaptive Control System with a Reference Model
Source: designed by the authors.

For practical use, the presented scheme is implemented in the programming language C++ (version 6.0) with a short cycle. The long-cycle mode is used for more in-depth research.

4. Results

4.1. Strategizing Sustainable Development

Since part of the indicators of the air transport sustainable development depends on the GDP of Ukraine, there should be made a forecast of the real GDP, assuming the maximum of all expert estimates (-20; -45%) of a drop of 45% and possible scenarios of its recovery (*Figure 3*).

From this graph, it follows that under the scenario of 2.3% annual growth, reaching the level of real GDP of the pre-war period (2021) is possible only in 2048, so this scenario will not be considered. Having set the forecast values of the GDP deflator, there will be obtained the values of the nominal GDP of Ukraine, which, in combination with official statistical data (2010-2021) and model calculations, make it possible to obtain the forecast values of the indicators of the sustainable development of air transport at the end of 2022.

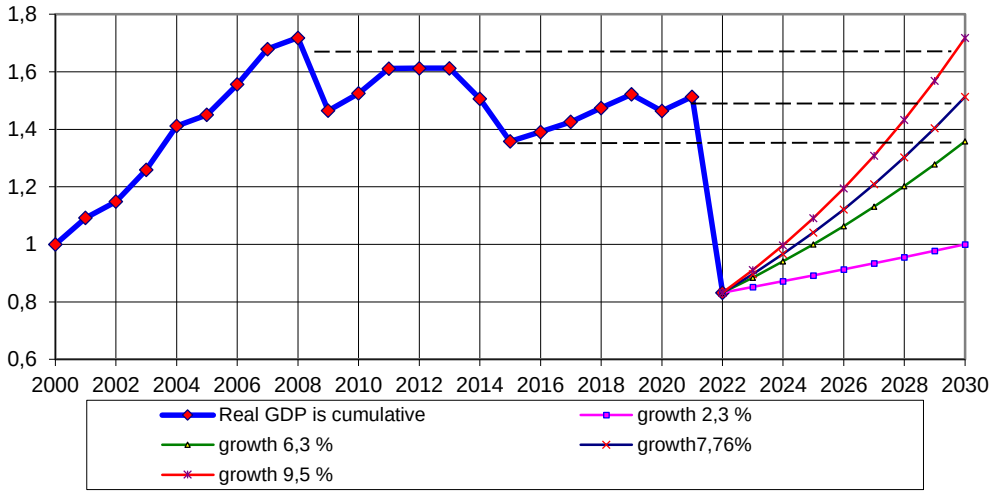

Figure 3. Real GDP of Ukraine with Strategic Growth Scenarios
Source: own elaboration.

The integral convolution of indicators and their limit values according to the modern methodology for determining the level of sustainable development gives the following picture of the current state of air transport at the end of 2022 by components and as a whole (Figure 4).

As it follows from the calculations, all components of the sustainable development of air transport of Ukraine and the integral indicator as a whole are below the lower threshold value, that is, in the critical zone, which is the result of the military actions of the RF against Ukraine.

To develop strategic post-war reconstruction scenarios, there will be defined strategic goals and there will be built trajectories of the desired increase at the level of sustainable development (Figure 5).

So, there are three possible recovery scenarios in accordance with the given goals:

1. Realistic – reaching the lower threshold value.
2. Optimistic – reaching the average value between the lower optimal and lower threshold values of the integral index.
3. The scenario of entering the zone of optimal sustainable development - reaching the lower optimal value of the integral index.

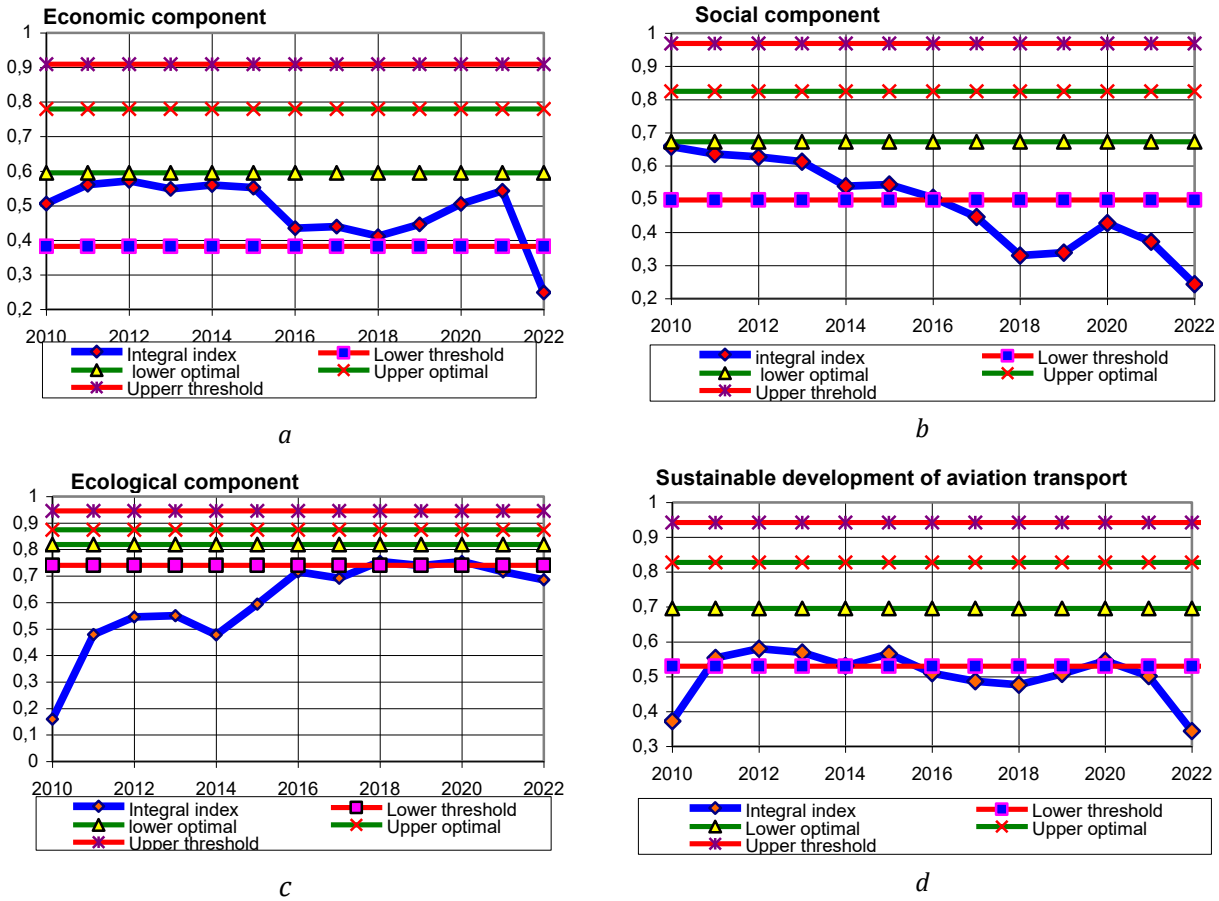

Figure 4. Dynamics of integrated indices of air transport of Ukraine
Source: own elaboration.

The construction of the growth trajectory to the defined goals requires the knowledge of the integral index each year, which, together with it, is laid down in the reference model of adaptive regulation for the synthesis of the latest values of the components (Table 2), and then their indicators (Table 3).

Table 2. Evaluating strategic guidelines of integral indices of the aviation transport sustainable development under scenarios of the post-war recovery

Components of sustainable development	2022	2023	2024	2025	2026	2027	2028	2029	2030
Realistic scenario	0.3440	0.3630	0.3831	0.4044	0.4268	0.4505	0.4755	0.5018	0.5298
Economic component	0.2492	0.2680	0.2882	0.3099	0.3330	0.3577	0.3841	0.4122	0.4421
Social component	0.2432	0.2629	0.2839	0.3063	0.3302	0.3557	0.3828	0.4117	0.4425
Ecological component	0.7458	0.7536	0.7621	0.7713	0.7813	0.7919	0.8034	0.8156	0.8287
Optimistic scenario	0.3440	0.3695	0.3971	0.4269	0.4589	0.4933	0.5303	0.5700	0.6127
Economic component	0.2492	0.2745	0.3025	0.3331	0.3666	0.4030	0.4427	0.4856	0.5319
Social component	0.2432	0.2696	0.2986	0.3303	0.3648	0.4023	0.4430	0.4870	0.5344
Ecological component	0.6856	0.6948	0.7057	0.7183	0.7329	0.7497	0.7690	0.7911	0.8162
Entering the zone of sustainable development	0.3440	0.3755	0.4101	0.4478	0.4891	0.5341	0.5832	0.6369	0.6957
Economic component	0.2492	0.2806	0.3157	0.3550	0.3985	0.4467	0.4999	0.5583	0.6224
Social component	0.2432	0.2759	0.3124	0.3529	0.3977	0.4472	0.5016	0.5613	0.6268
Ecological component	0.6856	0.6971	0.7110	0.7277	0.7476	0.7711	0.7987	0.8311	0.8687

The resulting dynamics of the components of the air transport sustainable development, in fact, compose a strategic plan for the post-war recovery of air transport if the calculations are followed. Moreover, the realistic scenario provides an almost pre-war level, the optimistic scenario exceeds the level of the air transport sustainable development over all the years of its existence, and the scenario of entering the optimal zone of sustainable development of the EU countries is the most desired state.

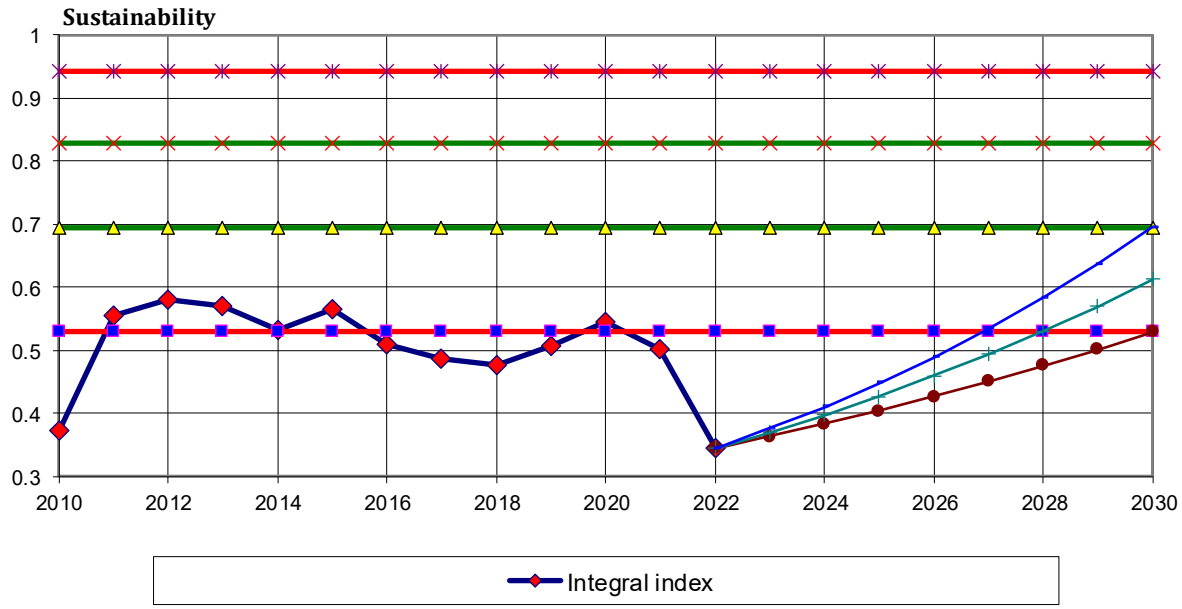

Figure 5. Dynamics and Strategic Scenarios of the Aviation Transport Sustainable Development
Source: own elaboration.

Therefore, the main task of the policy is to comply with the developed strategic plan through the development of appropriate regulatory measures to achieve the desired goal. Thus, the formation of justified response measures to military actions and adaptation of the trajectory of sustainable development to achieve strategically defined goals is ensured. And the transition from indicators to macro indicators makes it possible to imagine the necessary resources for implementing a strategic plan to maintain the trajectory of sustainable development.

For example, given the forecast values of the gross value added (GVA) deflator of air transport until 2030, we will get the strategic dynamics of real air traffic, which makes it possible to build its trajectory relative to 2010 for the analysis of the identified scenarios (*Figure 6*).

Table 3. Evaluating strategic guidelines of air transport indicators at the end of 2030 according to the post-war recovery scenarios

Components and indicators / Development scenarios	RS	OS	SD
Economic component	0.4421	0.5319	0.6224
Economic development	0.4081	0.5202	0.6348

- a share of air transport GVA in total GVA of transport and communication), % (S);	5.996	6.61	7.37
- a level of investment in air transport, % of air transport output (S);	6.05	8.75	11.53
- a level of export services of air transport, % of total exports of transport services (S);	15.72	21.2	27.18
- a level of import air transport services, % of total import of transport services (D);	13.67	10.86	6.86
- a level of shadowing of air transport, % of official GVA (D);	39.64	32.59	25.55
Technological development	0.3491	0.4204	0.4958
- a coefficient of manufacturability of air transport, the share of VDA in output (S);	0.4698	0.4812	0.4963
- capital utilization ratio (S);	0.7886	0.9128	1.0615
- a level of shadow capital load, % of official load (D);	30.69	29.38	27.71
- a level of using passenger capacity of aircraft (S), %;	29.44	36.78	45.11
- a level of fixed assets renewal, (S)%;	3.6	5.06	6.55
Production activity	0.7048	0.7339	0.7685
- cargo GDP transport intensity on air transport (ratio of cargo turnover to GDP) (D);	0.001	0.00092	0.0008
- passenger GDP transport intensity on air transport (ratio of cargo turnover to GDP) (D);	0.053	0.0465	0.0387
- an average distance of cargo transportation (ratio of cargo turnover to volume of cargo transportation) (S);	3367.1	3414.7	3473.7
- an average distance of passenger transportation (ratio of passenger turnover to passenger traffic volume) (S);	2266.5	2313.5	2371.4
- a ratio of domestic and international air transportations (S);	0.12	0.1313	0.1447
Aviation security:	0.3872	0.4881	0.5914
Execution of regular commercial, non-regular commercial and non-commercial flights[1]*:*	0.3434	0.4642	0.5852
- accident rates (catastrophe) (D);	0.0	0.0	0.0
- accident rates (accident) (D);	2.5725	2.067	1.538
- accident rates (serious incidents) (D);	4.3425	3.5225	2.666
Performing aviation works and training flights[2]	0.4462	0.5179	0.5988
- accident rates (catastrophe) (D);	6.3696	5.1333	3.676
- accident rates (accident) (D);	7.3343	6.7159	5.9421
- accident rates (serious incidents) (D);	6.7059	5.5572	4.1465
Social component	0.4424	0.5344	0.6268
- a level of wages in the output of air transport, Ukraine (S);	0.1747	0.2065	0.2407
- a level of employment in air transport, % (S);	61.04	66.5	72.75
- a population mobility ratio (S);	0.8107	1.1635	1.4915
- a level of official GVA created by shadow wages, % of official GVA of AT (D);	31.93	26.87	21.25
- a level of shadow employment, % of official employment (D);	37.3	31.23	24.94
Ecological component	0.7686	0.8162	0.8687
- a CO_2 emission level of Ukrainian air transport to GDP (D);	0.0343	0.0335	0.27
- a level of pollutants emissions into the atmosphere (D);	0.0015	0.0014	0.001
- a level of environmental costs of AT (S).	0.1505	0.169	0.185

Note: RS – Realistic scenario; OS – Optimistic scenario; SD – Entering the zone of sustainable development;

[1]The current values of the indicators and their threshold values for integral convolution to exclude zeros have been increased by 0.35; 0.35 and 0.41, respectively, to preserve the proportions, followed by a return to natural values in the reverse calculation.

[2]The current values of the indicators and their threshold values for integral convolution to exclude zeros have been increased by 0.41; 0.41 and 0.41, respectively, to preserve the proportions, followed by a return to the natural values when recalculating.

Source: model calculations.

From the above calculations (Figure 6), it can be seen that according to the realistic scenario, the real GVA of air transport remains at the level of 2021; according to the optimistic scenario – at the level 2018 year; according to the scenario of entering the optimal zone of sustainable development (achieving the lower optimal value by the integral index) – at the level of 2019.

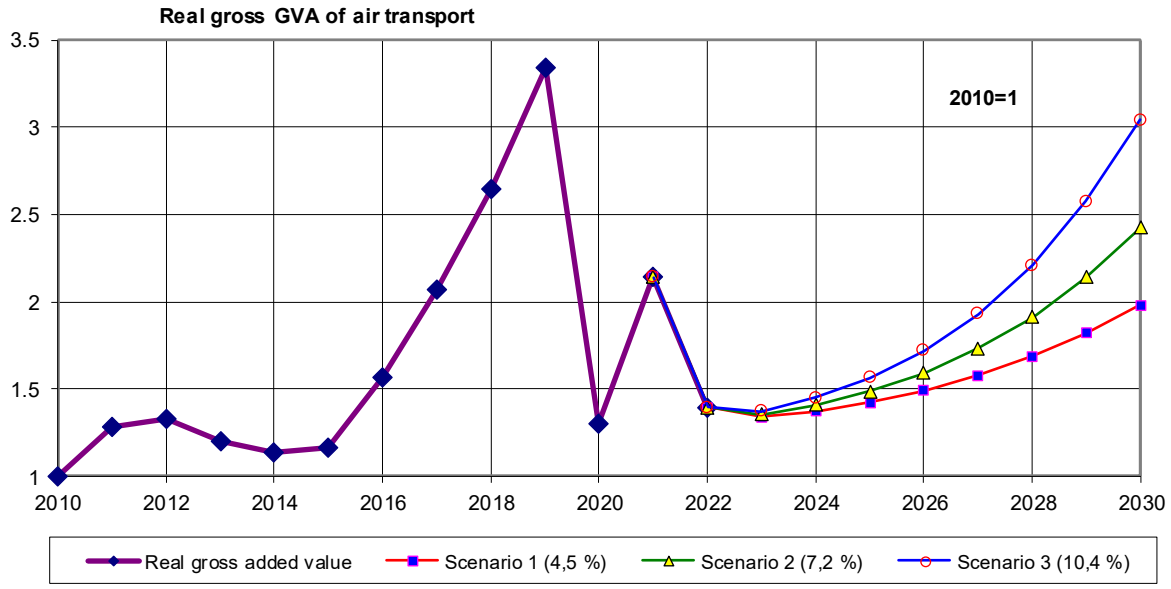

Figure 6. Strategic dynamics of the GVA of Air Transport
Source: own elaboration.

It should be noted that the implementation of the proposed scenarios is possible only under the condition of the total destruction of corruption and a significant reduction of the level of shadowing of the Ukrainian economy and aviation transport in particular to the level of the EU countries. All proposed post-war recovery scenarios are characterized by disproportionality in the development of components and indicators.

Therefore, the next stage after entering the optimal zone of limit values (see Figure 5) will be the achievement of the sustainable development criterion by the integral index of the air transport sustainable development – the average optimal value for all components and all indicators. But this means structural restructuring of Ukraine's economy and aviation transport in particular.

4.2. Strategic Guidelines for Air Transport Environmentalization in Ukraine in the Post-War Period

In order to determine the main measures of the air transport environmental strategy of Ukraine in accordance with the presented strategic scenarios for developing the national economy and air transport until 2030, there will be calculated the volumes of CO2 emissions, based on the proposed scenarios and the vector of limit values of the indicator "The level of CO2 emissions of air transport of Ukraine to GDP", kg/dollar GDP, which is a disincentive: the

lower critical level is 0.96; lower threshold – 0.82; the lower optimal – 0.51; upper optimal – 0.32; the upper threshold is 0.2; upper critical – 0.1. (*Figure 7*).

From the figure presented, it can be seen that in accordance with the growth of cargo and passenger transportation volumes, the total volume of CO2 emissions has a clear upward trend and can reach 372.7 thousand tons under a realistic scenario, or the highest value of 572.4 thousand tons under a sustainable development scenario. These maximum values are much smaller than previous estimates that were made before the war (Ovdiienko et al., 2021).

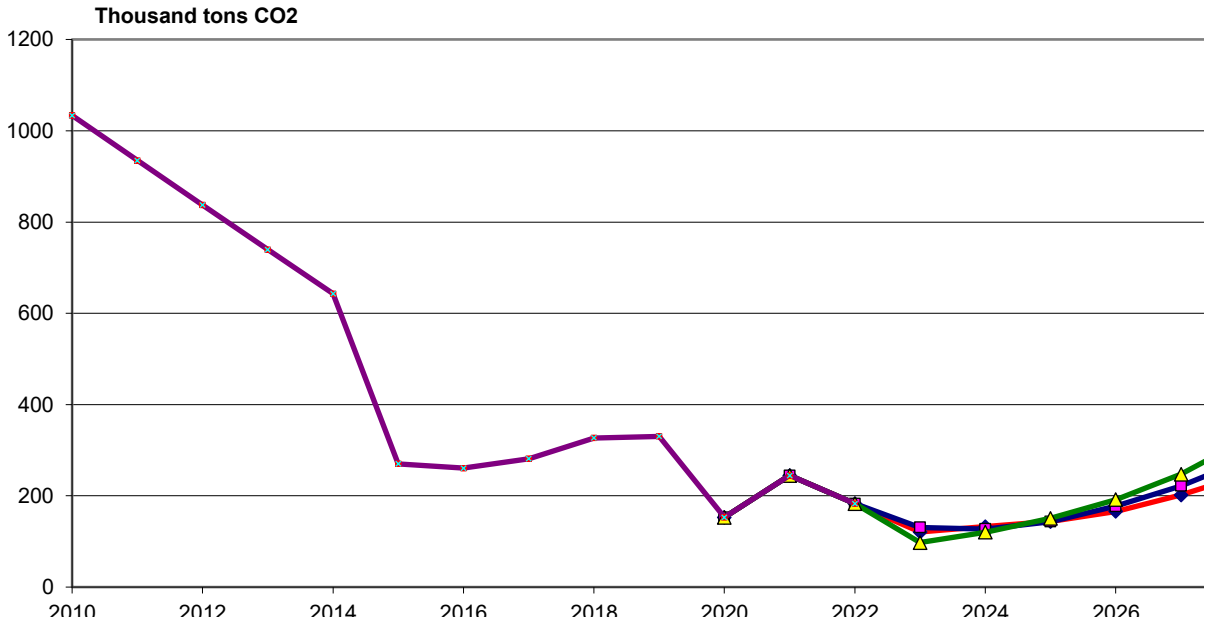

Figure 7. Strategic Scenarios of the Scope of CO_2 Emissions of Air Transport of Ukraine
Source: own elaboration.

In addition, the values of this indicator under the development scenarios are significantly better than its optimal values [0.51-0.32], but are limited to the upper threshold value of 0.2 for all scenarios, which corresponds to the best values of this indicator in Germany and significantly better than in Poland, the USA and the world as a whole, second only to France (0.11).

The recovery of aviation in the post-war period, according to our deep conviction, should involve a radical transformation of the existing state of the industry in accordance with the principles of sustainable development. If a simplified approach to the analysis of this trend is taken, it is possible to come to a conclusion that the closure of the airspace of Ukraine led to a sharp decrease in CO2 emissions. However, unfortunately, this is accompanied by a sharp decrease in the revenues of air transport enterprises, which in turn leads to a decrease in the replenishment of the state budget from their activities in general and, accordingly, to a decrease in costs for ecology, in particular.

It bears noting that in recent years, domestic airlines and airports have not actively developed programs for introducing "green" technological solutions into their operations. There is not a single airport in Ukraine that could be considered "green". Currently, the situation has worsened even more, as the Russian army has caused damage to airports amounting to UAH 200 billion. Of the 19 operational civilian airports, 12 have been destroyed or damaged. Unfortunately, the war continues. But everything can change after the end of hostilities. Joining the European Green Course aims to reduce transport emissions by 90% by 2050. The Ukrainian "Marshall Plan", presented in Lugano, provides for the reconstruction of 5-7 airports, which will be determined taking into account the goals of sustainable development and will provide for the reduction of harmful effects on the environment. The State Aviation Service of Ukraine and the Ministry of Digital Transformation of Ukraine have already created a portal "Fly Green: the way to the "greening" of aviation", which popularizes practical tools for implementing "green technologies" in airports and contains advice on managing financial and natural resources. In particular, this implies the use of special materials (low-carbon concrete, wood, photocatalytic membranes, biofuel, etc.), solar panels, ground electric transport, replacement of lighting with LED, installation of various energy conservation systems, etc.

It is common knowledge that in most countries of the world, the incentives to reduce harmful emissions are an effective system of taxation and fines for exceeding the established emission volumes (Boston Consulting Group, 2020). A carbon tax can be a powerful tool to reduce harmful emissions at a high rate because "the polluter pays" (Lilliestam et al., 2020). Environmental tax rates have been increased in Ukraine since January 1, 2022, in particular, the tax rate for emissions of carbon dioxide into the atmosphere is 30 hryvnias per ton (about 0.82 Euros at the current NBU exchange rate) (Low Carbon Ukraine Project, 2021), which is much less than the tax in the EU (4.3 euros in the current year). According to the recommendations of the Carbon Pricing Leadership Coalition, achieving the goals of the Paris Agreement is possible if the carbon price is set in the range of $40-80 per ton of CO2 emissions by 2030, and at the level of $130-150 per ton by 2050 (The World Bank, 2021).

Besides, on January 1, 2021, the system of monitoring, reporting and verification of greenhouse gas emissions, which is part of Directive 2003/87/EC38, began to operate in Ukraine. With the Law of Ukraine "On Principles of Monitoring, Reporting and Verification of Greenhouse Gas Emissions" entering into force, large and medium-sized industrial enterprises designated by the government are required to prepare plans for monitoring greenhouse gas emissions and report on emissions annually.

The next stage should be the creation of market mechanisms, which provide for the introduction of emission quotas in 2025 and the possibility of their sale. The emissions trading system provides for the establishment of a quantitative goal for reducing emissions at the state level, which can cover various sectors of the economy. Next, the government transforms this goal into obligations of enterprises and distributes free emission allowances among them. The number of free quotas is always less than the total emissions of enterprises. That is why those enterprises that have reduced greenhouse gas emissions can save money and

modernize at the expense of "green" loans or state subsidies. This directly concerns aviation transport enterprises, which will have to compete for free quotas for the volume of annual emissions or buy quotas from those enterprises that will have excess quotas.

4.3. Threats and Institutional Measures

4.3.1. Threats of Components and Indicators of Sustainable Development

To determine the list of threats, a criterion is used based on the distance from the point of sustainable development (the method of imbalances), which is considered the average value of the "homeostatic plateau". Thus, the social and economic components are the most lagging behind the optimal, and according to the indicators, the five most important threats are: the level of shadow intermediate consumption; the level of official GVA created by shadow wages; the level of shadow capital loading; the level of shading of air transport; a share of wages in the output. Therefore, as institutional measures to reduce the level of shadowing, the following is proposed: a legal limitation of the increase in the price of the product supplier for "firms-pads" to no more than 5-10% and redistribution of income between the employee and the employer through an increase in wages, which consists in a simultaneous reduction of the single social contribution (SSC), reducing the contribution to the Pension Fund of Ukraine and increasing personal income tax (PIT) and wages.

4.3.2. General Threats not Described by Indicators of Sustainable Development

Threats to Ukrainian airlines: a delay in the evacuation of unique aviation equipment abroad, problems with the leasing fleet of aircraft, a closure of Ukrainian airspace for civil aviation flights.

Threats to the system of airports and airfields of Ukraine: air and ground strikes on buildings, infrastructure and equipment; a closure of airspace for civil aviation flights.

Threats to the air traffic control system of Ukraine: air and ground strikes on buildings, infrastructure and equipment of the air traffic control system; a closure of airspace for civil aviation flights.

Threats to the aviation industry system of Ukraine: air and ground strikes on the design bureau, enterprises and infrastructure facilities of the aviation industry system; threats to serial production of aviation equipment during hostilities.

Threats to the aviation education and science system of Ukraine: air and ground strikes on buildings, infrastructure and equipment of the aviation education and science system; a delay or failure of the educational process and scientific activity of the aviation education and science system.

Institutional measures: updating the provisions of the Safety and Security State Programmes, the Concept of the State target scientific and technical program for the development of the aviation industry for 2021-2030; State target program for the development of airports for the period until 2023; development of mechanisms for partial support of Ukrainian airlines, airports, air traffic control system, aviation industry and aviation education & science system in the post-war period by the state, non-state investors and foreign investors; financial support for the recovery of aviation equipment; step-by-step optimization of the aircraft leasing fleet; implementation of the crisis management system elements under the force majeure conditions.

5. Discussion

Aviation constantly faces rapidly and constantly changing market conditions, intense competition, evolving business models and advances in technology (Kwilinski et al., 2020c; Kwilinski et al., 2021). This reality determines the need for a quick response to these challenges and requires a scientifically based strategic vision to preserve the trajectory of sustainable development (Czyżewski et al., 2019; Kostyrko et al., 2021; Szczepańska-Woszczyna & Gatnar, 2022). Moreover, such a formulation a priori assumes three components of development: social, ecological and economic, the balanced development of which occupies one of the first places among the main problems of developing territories and communities of all levels. The basis of sustainable development both at the state level and at the regional and local levels is the harmonization of economic, social and environmental components (Rajiani et al., 2018; Stuss et al., 2019; Kotowicz et al., 2022). The systematic coordination and balance of these three components and the development of a development strategy on this basis is a task of enormous complexity. To promote sustainable development, aviation stakeholders need to adopt innovative technologies and practices that reduce the industry's negative impacts while supporting economic growth and social development (Chygryn et al., 2018; Saługa et al., 2020; Kuzior & Kwilinski, 2022). This can include investments in renewable energy, eco-friendly aircraft designs, and improved air traffic management systems, among others (Drożdż & Mróz-Malik, 2017; Miskiewicz, 2020; Drożdż et al., 2020a; Lyulyov et al., 2021b; Miskiewicz et al, 2021). Additionally, collaboration between aviation stakeholders, policymakers, and local communities is essential to ensure that aviation transport supports sustainable development in a balanced and inclusive direction. One of the main tools for accomplishing tasks is foresight, which is based on the following methods: the Delphi method, identification of critical technologies; development of scenarios; expert panels; SWOT analysis; economic and mathematical modelling; brainstorming; regression analysis; extrapolation; simulation modelling; multi-criteria analysis and other classic forecasting methods. Unfortunately, expert evaluations are full of subjectivity and do not exclude fundamental errors. Known approaches to the classical forecasting of the integral indices' dynamics with the help of polynomials discredit economic-mathematical modelling in general and emasculate the essence of such a multidimensional concept as sustainable development or economic security. The use of the SWOT analysis method (Dacko-Pikiewicz, 2019; Kwilinski et al., 2020c; Stuss et al., 2019) can be considered a stage necessary for determining strategic directions of development, but completely

insufficient for substantiating quantitative strategic assessments of the future state. It is quite obvious that classical forecasting methods based on correlation-regression analysis are inappropriate here. First, forecasting provides a continuation of existing trends for the future, which is not always fulfilled; secondly, it always contains an error due to the innate pathology of errors due to the principle of forecasting "the past determines the future"; thirdly, it is necessary to know how the components and indicators of sustainable development should change to achieve the desired state, so completely different approaches are needed. That is why most of the developed strategies in Ukraine have a declarative nature without scientific substantiation of strategic guidelines through the declaration of necessary measures such as: provision, improvement, creation, formation, renewal, implementation, improvement, involvement, development, according to which it is impossible to monitor their implementation. In this regard, new approaches to identifying and strategizing the level of sustainable development and its components – economic, social and environmental – are gaining relevance.

6. Conclusions

Most approaches to strategizing the post-war recovery are based on the declaration of necessary measures and principles such as: provide, enhance, create, update, improve, attract, develop, etc. Unfortunately, the stated principles of restoring Ukraine's economy are only slogans, and some are more like ultimatums to the EU. Therefore, declaring the priority areas of such strategies does not ensure implementation of the expected targeted state policy. Modern identification methodology is used to determine the current level of sustainable development in the safety dimension. The identification result proves that the integral index of the sustainable development of air transport of Ukraine for the period of 2010-2022 is at the level of the lower threshold value, and in 2022 – in the critical zone, the strategic goals until 2030 follow – the achievement of the level of the lower threshold value (realistic scenario), reaching the average value between the lower threshold and lower optimal values (optimistic scenario), reaching the lower level of the optimal value (scenario of entering the optimal EU sustainable development zone).

For strategizing, it is proposed to use a new methodology, which, in contrast to classical forecasting methods (the past determines the future), uses the principle "the future is determined by the trajectory into the future" and provides a scientific basis for the strategic development plan with the following scenarios with the annual growth of real air transport air transport: realistic – 4.5%; optimistic – 7.2%; the scenario of entering the optimal zone of the EU countries) – 10.4% by 2030. The obtained strategic guidelines of indicators and key macro-indicators are, in fact, a strategic recovery plan, and their monitoring allows determining the effectiveness of the government's economic policy. Formulated strategic guidelines for the air transport environmentalization in Ukraine in the post-war period and strategic priorities for restoring the air transport infrastructure proved the need to pursue a course towards carbon neutrality. All considered strategic scenarios of sustainable development of aviation transport adhere to the level of CO2 emissions, kg/dollar GDP is no more than 0.2, which corresponds to the best value of this indicator in Germany and is significantly better than in Poland, the

USA and the world as a whole, second only to France (0.11). In order to maintain such a level of CO2 emissions, it is considered effective to stimulate the reduction of harmful emissions through an effective system of taxation and fines of those exceeding the established emission volumes.

The main threats to the aviation transport sustainable development in Ukraine are identified: those which are described by indicators of sustainable development using the method of imbalances – mainly indicators that reflect a shadow component of the aviation transport economy; those which are not described by indicators of sustainable development and reflect the general problems of air transport operation and management in Ukraine. In response to the threats and challenges of wartime, a complex of institutional measures was developed to ensure the specified scenarios of the post-war recovery of air transport in Ukraine. The proposed approaches to identifying and strategizing sustainable development, even in the post-war period, are universal, scientifically based and can be applied to any country or region.

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