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ANALYSIS OF THE MAIN ECO-ECONOMIC RISKS OF UKRAINIAN ENTERPRISES

Introduction. Contemporary Ukrainian enterprises have been operating under the influence of numerous economic and environmental threats that significantly affect their performance and development. Among the most serious challenges is the ongoing war that has resulted in the destruction of infrastructure, the suspension of production activities in certain regions, and disruptions to logistics chains, thereby complicating business operations and reducing investment attractiveness. At the same time, the environmental consequences of the war, including environmental pollution and ecosystem degradation, have created long-term ecological risks.

Problem Statement. The risk matrix has become an important tool for the systematic analysis of potential threats across various fields of activity, enabling the classification of risks according to their probability and potential impact. Its application facilitates effective risk management, reduces potential losses, and contributes to the sustainable development of enterprises.

Purpose. The purpose of this study is to test the applicability of the risk matrix method for the identification, assessment, and systematization of the principal eco-economic risks faced by Ukrainian industrial enterprises under conditions of war, energy instability, and environmental challenges, as well as to develop a set of practical measures aimed at reducing these risks and mitigating their adverse effects.

Materials and Methods. The study has employed the matrix method that involves constructing a risk matrix in which identified risks are distributed according to their significance. This approach has facilitated the prioritization of threats and supported the formulation of appropriate managerial decisions aimed at risk prevention and mitigation.

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Results. The study has demonstrated that eco-economic challenges constitute a critical factor affecting the operation and development of contemporary Ukrainian industrial enterprises, particularly under conditions of war and economic instability. The application of the risk matrix has enabled the assessment of potential threats, the identification of critical risks, and the development of targeted measures for their mitigation. The findings have confirmed the necessity of a systematic approach to risk management based on the implementation of innovative solutions, the attraction of financial resources, and the establishment of strategic partnerships with international organizations.

Conclusions. The results obtained have shown that the implementation of the proposed measures can enhance enterprise resilience, mitigate the negative consequences of eco-economic risks, and strengthen competitive advantages under conditions of ongoing global transformation and uncertainty.

Keywords: risk analysis, ESG standards, risk management, sustainable development, risk matrix, climate change, Corporate Social Responsibility.

Contemporary Ukrainian enterprises operating under wartime conditions face numerous environmental and economic risks that affect their performance, competitiveness, and long-term sustainability. The war in Ukraine has caused substantial environmental damage, estimated at billions of dollars, with long-lasting consequences for ecosystems and natural resources. As a result, Ukrainian businesses have been compelled to adapt to fundamentally new operating conditions. Mitigating environmental risks requires the adoption of green technologies and compliance with European environmental standards. Reducing economic threats, in turn, necessitates the diversification of sales markets, the implementation of anti-crisis management strategies, and the attraction of investment for business recovery and modernization.

Ukraine has joined the implementation of the sustainable development concept adopted at the United Nations Sustainable Development Summit of the 70th Session of the United Nations General Assembly held in New York in September 2015. The outcomes of the Summit were embodied in the document *Transforming Our World: the 2030 Agenda for Sustainable Development*, which established 17 Sustainable Development Goals (SDGs) and 169 associated targets [1]. A significant step toward implementing this concept in Ukraine has been the adoption of the Sustainable Development Goals of Ukraine until 2030 [2], further specified in the National Economic Strategy of Ukraine until 2030 [3]. Achieving the UN Sustainable Deve-

lopment Goals in Ukraine requires a balance between economic growth and environmental responsibility. However, enterprises continue to face a range of eco-economic risks that may hinder progress toward these objectives.

Ukrainian enterprises are also required to address increasing environmental pressures associated with global decarbonization trends, climate change, and evolving regulatory requirements. As part of its response to environmental challenges, Ukraine has been gradually harmonizing its environmental legislation with European standards, including, for example, the implementation of the provisions of Directive 2010/75/EU on industrial emissions. This process requires enterprises to invest substantial resources in the modernization of production facilities and environmental protection measures [4].

Due to their significant dependence on carbon-intensive technologies, many enterprises face the risk of additional costs associated with the Carbon Border Adjustment Mechanism (CBAM) when exporting goods to the European Union. The introduction of CBAM is driven primarily by the EU's increasing climate ambitions and its objective of achieving climate neutrality by 2050. Furthermore, traditional industries such as metallurgy, the chemical industry, and the energy sector exert considerable pressure on the environment, creating risks related to regulatory penalties, reputational damage, and conflicts with local communities. Equally important environmental risks arise from cli-

mate change and natural disasters. Extreme weather events, including droughts and floods, may adversely affect key sectors of the economy, particularly agriculture, logistics, and energy supply systems.

Ukraine's economy is influenced by both internal and external factors that contribute to business-environment instability. Among the most significant are the following.

Military risks. Russia's armed aggression has inflicted substantial losses on Ukrainian enterprises through the destruction of infrastructure, disruptions in raw-material supplies, labor-force migration, and a decline in effective consumer demand. As of November 2024, the environmental damage caused by military activities was estimated at approximately USD 71 billion [5].

Inflation and exchange-rate fluctuations. High inflation and the depreciation of the national currency affect production costs, the procurement of imported goods, and the financial stability of enterprises. According to the State Statistics Service of Ukraine, annual inflation reached 12% in 2024, representing an increase of 5.1 percentage points compared with 2023, while the hryvnia continued to weaken against the U.S. dollar [6, 7].

Energy shortages. Damage to energy infrastructure, restrictions on fuel imports, and interruptions in electricity supply pose serious threats to the stable operation of industrial facilities. As of May 2024, Ukraine had lost more than 70% of its electricity-generation capacity as a result of infrastructure damage and destruction, while the electricity deficit exceeded 7% during 2024 [7].

Logistics and supply-chain disruptions. Port blockades, damage to railway infrastructure, and shortages of transportation resources have complicated exports and hindered imports of critical materials. Although Ukraine's foreign trade demonstrated growth in 2024, the trade balance remained negative, reaching a deficit of USD 29.02 billion [6].

Reduced investment attractiveness. Owing to wartime risks and persistent economic uncertainty, both foreign and domestic investors remain cautious about business investments. According to the European Business Association (EBA), Ukraine's

Investment Attractiveness Index increased from 2.44 points in 2023 to 2.49 points out of 5 in 2024. During the first quarter of 2024, capital investment in Ukraine amounted to USD 152 billion [8].

Given these challenges — including military conflict, energy instability, increasing environmental requirements, and macroeconomic uncertainty — the risk matrix method represents a particularly relevant tool for assessing the eco-economic risks faced by Ukrainian enterprises. The flexibility and effectiveness of this method enable enterprises to identify critical risks, such as environmental penalties, operational disruptions caused by pollution incidents, and reputational threats. It also facilitates the development of risk-management strategies, including environmental insurance, production modernization, and compliance with ESG (Environmental, Social, and Governance) standards. Furthermore, the risk matrix supports the efficient allocation of resources for risk management, thereby reducing potential financial losses. Its application allows enterprises to systematize the analysis of eco-economic threats, which is especially important under conditions of heightened uncertainty. As a result, it contributes to enhanced competitiveness, reduced financial losses, and the achievement of sustainable development objectives.

In the context of these challenges, the need for a systematic approach to the analysis of eco-economic risks has become increasingly important. Such an approach is grounded in the concept of sustainable development established by the international document *Transforming Our World: the 2030 Agenda for Sustainable Development*, adopted at the United Nations Summit in 2015 [9]. This document established 17 Sustainable Development Goals (SDGs) and 169 associated targets intended to guide governments and business entities toward achieving a balance between economic growth, social well-being, and environmental sustainability.

Ukraine has officially endorsed the global sustainable development agenda, as reflected in the Presidential Decree of Ukraine No. 722/2019 establishing the Sustainable Development Goals (SDGs) at the national level [10] and in the National Eco-

conomic Strategy of Ukraine until 2030 [11], which provides for the integration of these goals into the country's recovery and development policies.

In the field of environmental regulation, a significant role is played by the harmonization of Ukrainian legislation with European Union standards. In particular, the implementation of Directive 2010/75/EU on industrial emissions requires enterprises to undertake substantial changes in their production processes and to enhance their level of environmental responsibility [12]. The Directive is based on the principles of pollution prevention and emission control and promotes an integrated approach to environmental risk management. At the same time, such regulatory requirements generate new economic risks, including increased modernization costs, potential financial penalties, and the need to prepare environmental disclosures in accordance with ESG (Environmental, Social, and Governance) standards.

The issue of managing eco-economic risks has attracted considerable scholarly attention within the fields of ecological economics, strategic management, and risk management. Studies [13, 14] emphasize that institutional instability and weak environmental policies may amplify risks for enterprises operating in transition economies. Consequently, adaptation to environmental change and internal threats has become an important subject of interdisciplinary research.

Within Ukrainian economic scholarship, a systematic approach to risk analysis has been developed in the works of O. Mazaraki, S. Lieonova, and I. Blank, who have emphasized the integration of risk management into enterprise strategic planning. In particular, I. A. Blank [15] has examined risk as a key component of financial strategy requiring structured analysis and continuous monitoring.

In the field of environmental management, the risk matrix method has been widely employed for both quantitative and qualitative assessment of environmental threats. As Peters and Hertwig [16] have stated, the risk matrix not only facilitates the visualization of risks but also enables the identification of critical points of impact that require im-

mediate attention. The effectiveness of this method has been demonstrated across numerous sectors, ranging from environmental protection to the energy industry [17].

According to the studies of R. Kaplan and M. Cooper [18], contemporary risk management should be based on the principles of flexibility, adaptability, and prevention. These principles are particularly relevant under wartime conditions, where risks are characterized by a high degree of uncertainty.

Furthermore, ESG transformation has become the subject of dedicated analysis in studies conducted by the European Commission European Commission [19] and the Organization for Economic Cooperation and Development (OECD) Organization for Economic Cooperation and Development [20], which have emphasized the necessity for companies to comply with environmental, social, and governance (ESG) criteria as a prerequisite for attracting investment and securing access to capital.

In the Ukrainian context, the roles of environmental insurance, the circular economy, and climate-change adaptation have been examined in the works of T. Vasyliieva, V. Shvydanenko, and A. Rozumovskyi, who have highlighted the importance of strategic planning for environmental security at the enterprise level. Tatomyr I. L. et al. [21] have stated that circular business models can serve as an effective instrument for reducing resource-related risks while enhancing the environmental reputation of companies.

The scholarly debate on eco-economic risks during the period 2022—2025 has focused primarily on the resilience of enterprises and supply chains to geopolitical shocks. A notable shift has occurred from static risk-assessment models toward dynamic frameworks capable of capturing the cumulative effects of war and climate change. Particularly important contributions have been made by Catherine Smaller [22] and Jagtap et al. [23], who have examined the vulnerability of food supply chains and documented a substantial decline in agricultural production in Ukraine as a consequen-

ce of military operations. Similarly, Zhang et al. [24] have investigated distortions in global commodity markets and assessed the role of the Black Sea Grain Initiative in stabilizing food prices.

Particular attention has also been devoted to the integration of environmental, social, and governance (ESG) factors into corporate strategy. Tsang et al. [25] have demonstrated that companies prioritizing ESG policies exhibit greater resilience during wartime crises. Comparable conclusions regarding the role of corporate social responsibility as a mechanism for maintaining operational stability have been reported by Wang Z. et al. [26].

Ukrainian scholars have concentrated primarily on post-war recovery strategies. Kovalenko [27] has substantiated a roadmap for the implementation of circular-economy principles as a key factor in strengthening Ukraine's economic security under conditions of transformational change. Androshchuk et al. [28] and Shcherbak et al. [29] have assessed the impact of environmental risks on local communities and regional ecosystems, pointing to critical contamination of soils and water resources by microplastics associated with emerging military technologies.

Issues related to risk assessment methodology have continued to evolve through the refinement of matrix-based approaches. Smetanko [30] has proposed the use of a significance–risk correlation matrix for planning internal audits and monitoring key performance indicators (KPIs) under conditions of uncertainty. In the energy sector, Güneş and Yalçın [31] have examined the bidirectional relationship between military conflicts and changes in the environmental policies of EU energy companies, which are compelled to balance decarbonization objectives with energy-security requirements.

The challenges of sustainable land use and institutional support for recovery have been addressed in the work of Boklah et al. [32], who have emphasized the importance of inclusive partnerships for overcoming the consequences of land degradation. Halunko et al. [33] and Shulga [34] have highlighted the need for a coordinated poli-

cy framework to ensure environmental sustainability and compliance with international environmental agreements.

Thus, the review of the scholarly literature has demonstrated the necessity of integrating traditional risk-assessment tools, such as the risk matrix, with contemporary sustainable-development concepts, ESG principles, innovative management practices, and considerations of geopolitical shocks. Such integration makes it possible to develop a comprehensive framework for managing eco-economic risks under conditions of environmental and economic instability.

The purpose of this study has been to validate the applicability of the risk matrix method for identifying, assessing, and systematizing the principal eco-economic risks faced by Ukrainian industrial enterprises under conditions of war, energy instability, and environmental challenges, as well as to develop a set of practical measures aimed at reducing these risks and mitigating their adverse effects in accordance with the Sustainable Development Goals.

The risk matrix is a quantitative and qualitative risk-assessment tool that enables enterprises to identify, classify, and manage risks based on two key parameters: the probability of occurrence and the magnitude of impact. The method involves constructing a matrix in which risks are categorized according to their significance, thereby facilitating informed managerial decisions regarding risk mitigation and prevention.

CHARACTERISTICS OF THE RISK MATRIX METHOD

1. Theoretical foundation. The risk matrix is grounded in the principles of probability theory and decision theory under conditions of uncertainty. It is widely employed within the framework of Enterprise Risk Management (ERM), which advocates a systematic approach to the identification, analysis, response, and monitoring of risks across an enterprise's strategic, operational, and financial activities.

2. *Matrix construction methodology.* A risk assessment matrix is typically constructed as a two-dimensional table in which one axis represents the probability of risk occurrence, while the other reflects the magnitude of the risk's impact on enterprise operations. Each identified risk is positioned within the corresponding matrix cell, making it possible to classify risks according to their significance, prioritize risk-management measures, and determine the need for mitigation strategies or adaptive responses.

3. *Advantages of the risk matrix approach.* The principal advantages of the risk matrix include the formalization of the risk-management process, the possibility of both quantitative and qualitative risk assessment, the objectivity and verifiability of evaluation results, and its adaptability to various industries and types of enterprises.

Thus, the risk assessment matrix constitutes a scientifically grounded tool that enables enterprises to adopt a structured approach to risk management. Its application promotes transparency, consistency, and strategic orientation in an increasingly uncertain business environment.

The significance of the risk matrix method lies in its versatility, simplicity, and practical effectiveness. The method is applicable across a wide range of sectors, including environmental management, economics, manufacturing, information technology, healthcare, and energy. Its visual representation of risks in matrix form facilitates the rapid identification of the most critical threats. Furthermore, it supports the prioritization of risks by enabling enterprises to focus resources on those threats characterized by both high probability and substantial impact. As a result, the method enhances the effectiveness of risk management, reduces the likelihood of unforeseen losses, and assists enterprises in anticipating and mitigating potential adverse consequences.

Accordingly, the risk matrix was developed through the following key stages:

- ◆ Preparatory stage. At this stage, the objectives and tasks of the method validation were defined; the accuracy of the approach was evaluated; po-

tential limitations and weaknesses were identified; and the methodology was adapted to the actual operating conditions of Ukrainian industrial enterprises. In addition, an appropriate methodological framework and evaluation criteria for the expert group were selected to ensure the reliable interpretation of the results.

- ◆ Data collection and processing. Experts examined the environmental and economic conditions under which Ukrainian industrial enterprises operate in the current crisis environment. The principal eco-economic risks were identified, classified, and grouped according to the key categories associated with the implementation of Ukraine's Sustainable Development Goals (SDGs).
- ◆ Risk assessment and risk matrix construction. Experts identified and evaluated the principal eco-economic risks (R1—R15) affecting the financial and operational performance of enterprises. These risks were assessed using a significance coefficient ranging from 0.1 to 1.0, where 0.1 denotes the lowest level of significance and 1.0 the highest. The assessments were derived through expert evaluation. For interval-based assessment during matrix construction, a risk-rating scale was employed, incorporating the likelihood categories *high*, *substantial*, *moderate*, *low*, and *minimal*. In constructing the eco-economic risk matrix for Ukrainian industrial enterprises, four risk levels corresponding to the linguistic assessments *low*, *moderate*, *high*, and *critical* were adopted.
- ◆ Development of eco-economic risk management measures. A comprehensive set of measures has been developed to reduce risk exposure and mitigate adverse consequences.

To ensure the objectivity of the risk matrix validation, a combination of general scientific and specialized research methods has been employed. In particular, the methods of analysis and synthesis have enabled the identification and structuring of fifteen key eco-economic threats, which have been grouped into five categories aligned with the Sustainable Development Goals. The comparative

method has been used to evaluate the likelihood of risk occurrence and the magnitude of its impact on business operations, providing the basis for ranking risks according to their significance, from moderate to critical. The method of generalization has been applied to formulate strategic recommendations and comprehensive mitigation measures within an integrated risk-management framework.

The expert assessment method has served as the foundation for the quantitative interpretation of qualitative indicators. Within this framework, a panel of experts has assigned significance scores to each factor on a scale ranging from 0.1 to 1.0, thereby ensuring the reliability and verifiability of the input data used for matrix construction. In addition, systems analysis has made it possible to examine the nonlinear interrelationships between enterprise financial resilience and the environmental challenges arising under wartime conditions.

The matrix is based on two principal dimensions: the probability of risk occurrence and the potential impact of the risk. This simple yet effective structure facilitates the identification of the most critical threats and supports the prioritization of risk-management efforts. The validation of the eco-economic risk matrix for Ukrainian enterprises has involved its practical application to the assessment of risks arising from the interaction between enterprises and their environmental and economic surroundings.

For the purposes of validation, the principal risks affecting Ukrainian enterprises have been identified and evaluated by a panel of experts using a significance coefficient on a scale from 0.1 to 1.0, where 0.1 indicates negligible impact and 1.0 denotes critical impact (Table 1).

To determine the interval assessment values used in constructing the risk matrix, a risk-rating scale is proposed. This scale assigns both a probability value and a corresponding likelihood category for risk occurrence (Table 2).

The interval values of risk probability range from 0% to 100%, where 0% corresponds to a negligible impact associated with a minimal probability of occurrence of the i -th risk, and 100% corre-

sponds to a critical impact associated with a high probability of occurrence of the i -th risk.

The risk matrix is based on two principal parameters:

1. Probability of risk occurrence — categorized as *high* (5), *substantial* (4), *moderate* (3), *low* (2), and *minimal* (1), according to the scale presented in Table 2.

2. Degree of impact on the enterprise — categorized as *negligible* (1), *moderate* (2), *significant* (3), *high* (4), and *critical* (5), based on the significance coefficient corresponding to the level of impact presented in Table 1.

In accordance with the objectives of this study, the eco-economic risks of Ukrainian enterprises have been classified into four categories corresponding to the linguistic risk assessments low, moderate, high, and critical. Based on the expert evaluation, in which significance coefficients range from 0 to 1, the following intervals have been established:

- ◆ Critical risk: [0.9; 1.0];
- ◆ High risk: [0.7; 0.9];
- ◆ Moderate risk: [0.4; 0.7];
- ◆ Low risk: [0.0; 0.9].

Figure 1 illustrates the distribution of eco-economic risks according to their significance coefficients, taking into account both the degree of impact and the probability of occurrence. Particular attention is given to the critical-risk category, which is characterized by the highest levels of probability and impact on enterprise operations and may result in severe adverse consequences for business performance.

The analysis indicates that high energy intensity of production (R1), substantial expenditures on environmental modernization (R11), investment outflows caused by the war (R12), and labor-force migration (R13) constitute the most critical risks facing Ukrainian enterprises. These risks may lead to the following consequences:

- ◆ R1 — High energy intensity of production: increased production costs, heightened vulnerability to changes in energy policy, and potential loss of market positions due to elevated manufacturing costs;

- ◆ R11 — Substantial expenditures on environmental modernization: reduced enterprise profitability as a result of significant compliance costs, diminished competitiveness in international markets due to delays in adopting environmental standards, and potential penalties or sanctions arising from non-compliance with new regulatory requirements;
- ◆ R12 — Investment outflows caused by the war: contraction of production activities and suspen-

Table 1. Key Eco-Economic Risks of Ukrainian Industrial Enterprises within the Framework of the Sustainable Development Goals

Risk group	Description	Impact significance coefficient
1. Resource- and energy-efficiency-related risks (SDGs 7, 12, 13)	<i>High energy intensity of production</i> (R1) — significant dependence on fossil fuels makes enterprises vulnerable to rising energy tariffs and energy crises	0.9
	<i>Shortage of critical resources</i> (R2) — depletion of natural resources and limited access to water and land resources (particularly due to hostilities)	0.85
	<i>Low level of circular economy development</i> (R3) — insufficient development of recycling technologies, leading to increased volumes of industrial waste	0.7
2. Environmental regulation and export restriction risks (SDGs 9, 12, 17)	<i>Implementation of European environmental standards</i> (R4) — to integrate into the European market, enterprises are required to reduce CO ₂ emissions and comply with ESG (Environmental, Social, and Governance) requirements	0.6
	<i>Introduction of the CBAM mechanism</i> (R5) (<i>Carbon Border Adjustment Mechanism of the EU</i>) — a threat of increased customs duties on Ukrainian products with high CO ₂ emissions	0.8
	<i>Uncertainty of state environmental policy</i> (R6) — frequent regulatory changes may generate additional compliance costs for enterprises	0.75
3. Climate change and environmental degradation risks (SDGs 13, 15)	<i>Climate change impacts</i> (R7) — droughts, floods, and extreme weather events affect the agricultural sector, energy production, and logistics	0.7
	<i>Environmental pollution</i> (R8) — accumulation of industrial waste and contamination of water and soil create risks for sustainable development	0.8
	<i>Decline in biodiversity</i> (R9) — deforestation and ecosystem degradation caused by industrial activities	0.6
4. Financial and investment risks (SDGs 8, 9, 17)	<i>Insufficient “green” financing</i> (R10) — limited access of enterprises to environmental investments and international sustainable development funds.	0.85
	<i>High costs of environmental modernization</i> (R11) — enterprises often cannot afford the implementation of energy-efficient and low-carbon technologies	0.9
	<i>Capital outflow due to the war</i> (R12) — international companies may avoid investing in Ukraine due to high risks	1.0
5. Socio-economic risks (SDGs 1, 3, 8)	<i>Labor migration</i> (R13) — shortage of qualified workforce due to population outflow abroad	0.9
	<i>Deterioration of public health</i> (R14) — environmental threats (polluted air and water) increase morbidity rates, thereby reducing labor productivity	0.75
	<i>Conflicts between business and society</i> (R15) — environmental protests and disputes related to pollution may lead to reputational losses for enterprises	0.7

Source: prepared by the authors.

sion of operations at individual enterprises, job losses and declining regional economic activity, as well as the relocation of businesses to other countries, thereby adversely affecting the national economy;

- ◆ R13 — Labor-force migration: declining productivity and product quality resulting from workforce shortages and insufficient employee qualifications, together with increased expenditures on staff training and recruitment.

These four risks have been classified as critical because they directly affect business resilience and the ability of enterprises to maintain sustainable operations in the long term. Investment outflows and labor-force migration are particularly alarming, as they substantially constrain the capacity of enterprises to develop and adapt to changing economic conditions.

Figure 2 presents the distribution of eco-economic risks according to their significance coefficients, taking into account both the degree of impact and the probability of occurrence within the high-risk category. Risks assigned to this category are characterized by a substantial likelihood of occurrence and may result in serious adverse consequences for enterprise performance. Although their potential impact is lower than that of critical risks, they nevertheless require immediate attention and proactive risk-management measures.

Thus, the analysis indicates that shortages of critical resources (R2), the low level of circular-economy implementation (R3), the introduction of the

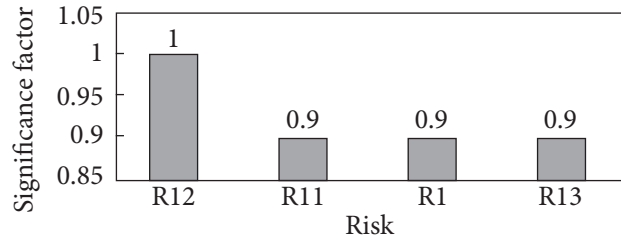


Fig. 1. Distribution of eco-economic risks by impact significance coefficient and probability of occurrence within the “critical risk” category

Source: prepared by the authors.

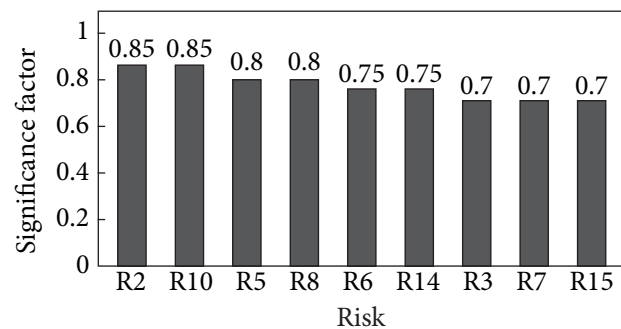


Fig. 2. Distribution of eco-economic risks by impact significance coefficient and probability of occurrence within the “high-risk” category

Source: prepared by the authors.

Carbon Border Adjustment Mechanism (CBAM) (R5), uncertainty in environmental policy (R6), climate change (R7), environmental pollution (R8), insufficient access to green financing (R10), deterioration of public health (R14), and reputational

Table 2. Risk Level Assessment Scale

Risk probability level	Probability, %	Description
High	over 90	High certainty of risk occurrence in the short term, potentially multiple times
Substantial	60—90	Certain probability of risk occurrence in the short term
Moderate	40—60	The risk can be avoided through systematic and well-structured management
Low	10—30	The risk is unlikely under existing business processes and requires additional investigation
Minimal	Under 10	The probability of risk occurrence is very low; the risk is unlikely under current business processes

Source: prepared by the authors.

risks associated with environmental and social responsibility issues (R15) constitute high-level risks, as they have a substantial impact on enterprise stability and performance. These risks may lead to the following consequences:

- ◆ R2 — Shortages of critical resources: production interruptions or reductions caused by shortages of raw materials and inputs; increased production costs, leading to reduced competitiveness; and the need to identify alternative resources or modify existing business models;
- ◆ R3 — Low level of circular-economy implementation: missed opportunities for resource efficiency and cost reduction; increased dependence on primary raw materials; and potential penalties or restrictions arising from non-compliance with environmental requirements;
- ◆ R5 — Introduction of the Carbon Border Adjustment Mechanism (CBAM): higher costs associated with exporting products to the European Union; the need for substantial environmental investments to reduce the carbon footprint of production; and the potential loss of access to European markets due to declining export profitability;
- ◆ R6 — Uncertainty in environmental policy: difficulties in forecasting expenditures related to environmental compliance; insufficient support for business-led environmental initiatives; and the risk of losing competitiveness relative to countries with more predictable environmental regulatory frameworks;
- ◆ R7 — Climate change: deterioration of production conditions, particularly in the agricultural sector; the need for additional expenditures to adapt to changing climatic conditions; disruptions to supply chains; and increased transportation-related risks;
- ◆ R8 — Environmental pollution: higher environmental taxes and penalties; erosion of public trust and increased tensions with local communities; and restrictions on business activities resulting from stricter environmental regulations;
- ◆ R10 — Insufficient access to green financing: slower implementation of environmental mo-

dernization projects; reduced competitiveness in international markets; and difficulties in meeting environmental requirements, potentially resulting in penalties and regulatory restrictions;

- ◆ R14 — Deterioration of public health: increased expenditures on employee health insurance and social support programs; and possible declines in product quality due to shortages of qualified personnel;
- ◆ R15 — Reputational risks associated with environmental and social responsibility issues: reputational damage and potential consumer boycotts; tighter regulatory oversight and more frequent inspections by public authorities; and an increased risk of social protests and legal claims.

Collectively, these risks represent a significant threat to enterprise sustainability and competitiveness. Although their impact is generally less severe than that of the critical-risk category, their relatively high probability of occurrence and potentially substantial economic consequences necessitate continuous monitoring and the implementation of targeted risk-mitigation measures.

These nine risks have been classified as high-level risks, although they are not as critical as, for example, investment outflows or labor shortages. Particularly significant among them are shortages of critical resources, the implementation of the Carbon Border Adjustment Mechanism (CBAM), and environmental pollution, as these factors directly affect operating costs and business competitiveness.

Figure 3 presents the distribution of eco-economic risks according to their significance coefficients, taking into account both the degree of impact and the probability of occurrence within the moderate-risk category. Risks in this category are characterized by a moderate likelihood of occurrence and may result in noticeable, although not critical, adverse consequences for enterprise performance. While such risks do not pose an immediate threat to business continuity, they nevertheless require ongoing monitoring and appropriate management measures.

According to the analysis, the implementation of European (international) environmental standards (R4) and biodiversity loss (R9) fall within the moderate-risk category in terms of their impact on enterprise performance. Specifically, these risks may lead to the following consequences:

- ◆ R4 — Implementation of European (international) environmental standards: short-term challenges associated with increased expenditures on production modernization; long-term benefits through expanded export opportunities and improved business efficiency; and a risk of declining competitiveness for enterprises that fail to adapt to the new regulatory requirements in a timely manner;
- ◆ R9 — Biodiversity loss: stricter environmental requirements and conservation measures may increase operating costs, worsen conditions for the agricultural sector and related industries, and intensify social pressure as well as potential conflicts with local communities arising from adverse environmental impacts.

These two risks are classified as moderate, as they do not pose an immediate threat to business operations but may have a substantial impact in the longer term. The principal challenges are associated with adapting to evolving environmental standards and increasingly stringent ecological requirements, which necessitate a proactive managerial approach.

The low-risk category comprises risks characterized by a low probability of occurrence and a limited impact on enterprise activities. Such risks do not require immediate intervention, although they may still be monitored to enhance overall organizational resilience. According to the expert assessment, no risks were assigned to this category (Table 2), as all identified eco-economic risks were found to have at least a moderate level of significance.

Based on the expert evaluation results, a risk matrix of eco-economic risks for Ukrainian industrial enterprises was developed (Fig. 4). The risk assessment framework combines two key dimensions: the significance coefficient reflecting the magni-

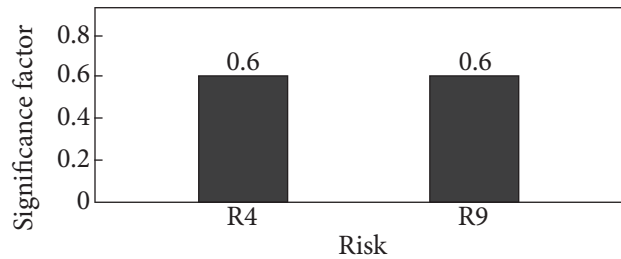


Fig. 3. Distribution of eco-economic risks by impact significance coefficient and probability of occurrence within the “moderate- risk” category

Source: prepared by the authors.

tude of impact (Table 1) and the probability of risk occurrence (Table 2). This matrix provides a systematic basis for identifying priority risk areas and supports informed managerial decision-making aimed at mitigating adverse environmental and economic impacts.

The developed risk matrix provides a clear visual representation of the significance of each identified risk. Specifically, red cells indicate *critical risks*, orange cells denote *high risks*, yellow cells represent *moderate risks*, whereas green cells correspond to *low* and *minimal risks*. No risks were assigned to the latter category in the present study, as expert assessments indicated that all identified eco-economic risks have substantial significance.

The obtained results are consistent with the findings of international studies, while also reflecting specific national characteristics. Comparison with the works of Smaller [22] and Jagtap et al. [23] confirms that systemic shocks, such as war, transform the structure of risks from local disturbances into disruptions affecting global supply chains. However, whereas these authors primarily focus on food security, the present study highlights the critical role of energy-related (R1) and investment-related (R12) factors for industrial enterprises.

A comparison with the approach proposed by Smetanko [30], based on a *materiality–risk correlation matrix*, demonstrates that the application of the proposed 5×5 risk matrix is more appropriate under conditions of high uncertainty, where precise KPI-based financial assessment is compli-

		Impact				
		Low (1)	Moderate (2)	Substantial (3)	High (4)	Critical (5)
Probability	High (5)	Moderate	High (R2)	High (R5)	Critical (R1, 11)	Critical (R12)
	Substantial (4)	Low	Moderate (R4)	High (R3, 8)	High (R6)	Critical (R13)
	Moderate (3)	Low	Low	Moderate (R9)	High (R7, 15)	High (R14)
	Low (2)	Low	Low	Low	Moderate	High (R10)
	Minimal (1)	Low	Low	Low	Low	Moderate

Fig. 4. Eco-economic risk matrix of Ukrainian industrial enterprises

Source: prepared by the authors.

cated by wartime circumstances. At the same time, Smetanko emphasizes the importance of internal auditing, an aspect incorporated in the present study through the proposed mitigation measures addressing R11 (environmental modernization costs).

Table 3. A Set of Measures to Reduce and Mitigate the Negative Impacts of Eco-Economic Risks in the Activities of Ukrainian Enterprises

Impact assessment	Risk	Managerial decisions
Critical risks (the highest priority)	High energy intensity of production (0.9) (R1)	Implementation of energy-efficient technologies and modernization of equipment Transition to alternative and renewable energy sources Optimization of energy consumption through digital technologies and energy-use monitoring systems
	High costs of environmental modernization (0.9) (R11)	Attraction of state and international funding programs for “green” initiatives Development of a phased environmental modernization strategy focused on the most cost-effective measures Use of preferential credit mechanisms and tax incentives
	Capital outflow due to the war (1.0) (R12)	Creation of favorable conditions for investors, including investment insurance and state guarantees Diversification of markets and suppliers to reduce dependence on external factors Lobbying for international financial support and economic recovery programs
	Labor force migration (0.9) (R13)	Implementation of training and retraining programs for employees Improvement of working conditions and provision of competitive wages to retain skilled personnel Simplification of procedures for attracting foreign and domestic workers
High risks (important priority)	Deficit of critical resources (0.85) (R2)	Development of alternative raw material sources and implementation of recycling technologies Optimization of supply chains and diversification of suppliers Use of local resources and development of closed-loop production cycles
	Insufficient access to green financing (0.85) (R10)	Attraction of international grants and funds Development of partnerships with financial institutions Optimization of internal resource utilization

Impact assessment	Risk	Managerial decisions
Moderate risks (strategic management)	Deterioration of public health (0.75) (R14)	Implementation of filtration systems to reduce emissions and transition to cleaner technologies Organization of regular medical check-ups for employees and improvement of workplace ventilation and protection systems Introduction of insurance programs and healthcare benefits for employees
	Low level of circular economy development (0.7) (R3)	Implementation of reuse and waste recycling technologies Use of economic incentives (tax benefits, state grants) for enterprises adopting circular economy models Promotion of the circular economy concept among entrepreneurs
	Conflicts between business and society (0.7) (R15)	Regular meetings with representatives of local self-government Public consultations prior to the launch of new projects and implementation of feedback mechanisms Investment in environmental, educational, and social initiatives, along with a transparent environmental policy
	Introduction of the CBAM mechanism (0.8) (R5)	Reduction of carbon footprint through production modernization and transition to "green" energy sources Assessment of the impact of the CBAM mechanism on enterprise exports and development of an adaptation plan Revision of business models to shift focus toward environmentally friendly products
	Uncertainty of state environmental policy (0.75) (R6)	Cooperation between business and the state through industry associations to ensure the development of transparent environmental policies Continuous monitoring of legislative changes and timely adaptation to new regulatory requirements Implementation of internal corporate environmental standards as a preventive measure
	Climate change (0.7) (R7)	Development of climate-resilient technologies and adaptation mechanisms Transition to resource-efficient production processes Use of climate change forecasts for strategic business planning
	Environmental pollution (0.8) (R8)	Implementation of environmental monitoring systems and emission control mechanisms Adoption of zero-waste technologies and efficient waste management and disposal methods Compliance with international environmental safety standards
	Implementation of European environmental standards (0.6) (R4)	Gradual adaptation to European standards through phased modernization of production facilities Utilization of international support programs to finance environmental initiatives Conducting environmental compliance audits to identify problem areas
	Biodiversity loss (0.6) (R9)	Implementation of environmental management systems at enterprises Application of resource-efficient technologies and reduction of environmental impact Partnership with environmental organizations for the development of nature protection programs

Source: prepared by the authors.

From a methodological perspective, the selected matrix-based approach is less labor-intensive than the Analytic Hierarchy Process (AHP), which is commonly used for selecting technical alternatives under relatively stable conditions. Although AHP provides greater mathematical precision, the risk matrix offers the speed of decision-making required in wartime environments. Compared with the Failure Mode and Effects Analysis (FMEA) method, the proposed matrix operates with two dimensions — probability and impact — whereas FMEA introduces a third parameter, *detectability*. Under military conditions, where threats such as missile attacks and infrastructure destruction are often immediately observable, a two-dimensional matrix is more suitable for strategic risk management.

The assessment of the Carbon Border Adjustment Mechanism (CBAM) risk (R5, classified as *high*) is consistent with projections reported by the KSE Institute [36], according to which potential EBITDA losses for exporters may amount to hundreds of millions of euros annually. The present analysis extends these findings by suggesting that, for Ukraine, CBAM should be viewed not only as a fiscal and regulatory challenge but also as a catalyst for the wider adoption of green power purchase agreements (PPAs) following the country's integration into the ENTSO-E electricity network [37].

Based on the identified risk profile, a set of recommendations has been developed to facilitate the implementation of organizational and managerial changes aimed at improving the effectiveness of industrial enterprise management. Accordingly, a comprehensive package of measures has been proposed to reduce the identified risks and mitigate their adverse consequences (Table 3).

Thus, critical risks (0.9–1.0) require immediate management actions because of their direct impact on enterprise operations, particularly in the areas of energy efficiency, investment availability, and labor resources. High risks (0.7–0.85) demand proactive strategic management, especially with regard to resource security and compliance

with international environmental requirements. Moderate risks (around 0.6) call for long-term planning and gradual adaptation measures to prevent potential adverse consequences in the future.

The implementation of the proposed measures enables enterprises to reduce risk exposure, enhance competitiveness, and ensure sustainable development even under challenging economic conditions.

The risk matrix enables enterprises to assess potential threats, identify critical vulnerabilities, and implement appropriate mitigation measures. Such an approach contributes to reducing both environmental damage and economic losses.

The application of the risk matrix method has confirmed that, for Ukrainian industrial enterprises during 2022–2025, the most destructive threats have been those related to energy security (R1), shortages of investment capital (R12), and the large-scale migration of skilled personnel (R13). The study has also demonstrated that the high-risk status of the Carbon Border Adjustment Mechanism (CBAM) (R5) transforms environmental modernization from a formal regulatory requirement into a critical prerequisite for maintaining access to EU markets.

The findings have further shown that the adaptability of Ukrainian businesses under martial law increasingly depends on the integration of circular economy principles and the “Build Back Better” strategy, which make it possible to transform infrastructure losses into opportunities for technological modernization and sustainable growth.

Future research should focus on moving beyond qualitative expert-based assessments toward dynamic quantitative modelling of the financial consequences of risks. In particular, the application of Monte Carlo simulation could provide more robust forecasts of the resilience of investment projects under conditions of uncertainty. Another promising direction is the extension of the analysis to small and medium-sized enterprises (SMEs) and the agri-food sector, which face specific challenges related to land-resource management, environmental security, and climate-related risks.

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АНАЛІЗ ОСНОВНИХ ЕКОЛОГО-ЕКОНОМІЧНИХ РИЗИКІВ ПІДПРИЄМСТВ УКРАЇНИ

Вступ. Сучасні підприємства України зіштовхуються із низкою економічних та екологічних загроз, які суттєво впливають на їхню діяльність і розвиток. Серед основних загроз — триваюча війна, яка спричинила руйнування інфраструктури, зупинку виробництва на окремих територіях і порушення логістичних ланцюгів, що ускладнює ведення бізнесу та знижує інвестиційну привабливість, а екологічною складовою війни є забруднення довкілля, яке спричиняє довгострокові екологічні проблеми.

Проблематика. Актуальним наразі є створення матриці ризиків як інструменту системного аналізу потенційних загроз у різних сферах діяльності — для класифікації ризиків за рівнем ймовірності та ступенем їх впливу. Її застосування дозволяє ефективно знижувати потенційні втрати та забезпечувати стабільний розвиток будь-якого підприємства.

Мета. Апробація методу матриці ризиків для ідентифікації, оцінки та систематизації основних еколого-економічних ризиків промислових підприємств України в умовах війни, енергетичної нестабільності й екологічних викликів, а також розробка комплексу практичних заходів для їх зниження й мінімізації негативного впливу.

Матеріали й методи. Застосовано матричний метод, який полягає у побудові матриці, де ризики розподіляються за рівнями значущості, що допомагає ухвалювати правильні управлінські рішення щодо їх зниження чи запобігання.

Результати. Доведено, що еколого-економічні виклики є критичними для сучасних промислових підприємств України, особливо в умовах війни та економічної нестабільності. Матриця ризиків дозволяє підприємству оцінити потенційні загрози, визначити критичні ризики та впровадити заходи для їх мінімізації. Необхідним є системне управління ризиками через впровадження інноваційних рішень, залучення фінансування та стратегічне партнерство з міжнародними структурами.

Висновки. Впровадження розроблених заходів допоможе підприємствам зберегти стійкість, мінімізувати негативні наслідки та посилити конкурентні переваги в умовах глобальних змін.

Ключові слова: аналіз ризиків, стандарти ESG, управління ризиками, сталий розвиток, ризик-матриця, кліматичні зміни, КСВ.