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Methodological Aspects for the Formation of a System of Indicators for Assessing Industrial Safety at the Regional Level

Abstract

The study explores methodological approaches to the establishment of a system of indicators for evaluating industrial safety at the regional level. The theoretical foundations, principles and criteria for constructing an indicator system are determined, with consideration given to the regional specifics of the socio-economic development. The purpose of the paper is twofold: firstly, to provide a robust theoretical foundation for the development of a system of indicators for evaluating industrial safety at the regional level; and secondly, to empirically assess the efficacy of the proposed methodology by applying it to the Black Sea region of Ukraine. *Methodology*. The methodological basis of the study is modern approaches to assessing industrial safety, which are based on systemic, indicator and integral approaches. To achieve the goal, a set of complementary methods was applied: logical-theoretical method (to clarify the essence of the "industrial safety" concept and determine its place in the structure of economic security); analytical method (to generalise scientific approaches to building indicator systems); indicator method (to form a system of indicators for assessing industrial safety, taking into account their stimulating or discouraging impact); statistical method (to collect, process and analyze empirical data for the Black Sea regions); indicator normalisation method (to ensure their comparability); integral assessment method (to determine the generalized level of industrial safety of the regions); comparison method (to identify interregional differences and trends); tabular method (to systematise the results of the analysis and present the data in a form convenient for interpretation). *Results*. The proposed methodological model for the formation of a system of indicators for assessing industrial safety includes nine key indicators. These indicators reflect the state of the industrial and agricultural sectors, the level of energy efficiency, innovative activity, the technical condition of fixed assets, economic efficiency and food stability. The criteria for the rationing indicators (by types of stimulants and The determination of disincentives is accompanied by the construction of a scale for the assessment of safety levels. The testing of the methodology by the example of Odesa, Mykolaiv and Kherson regions has demonstrated its practical applicability for a comprehensive assessment of industrial safety in regions. The findings indicated substantial variations in safety levels across different regions, with a low level recorded in the Odesa and Mykolaiv regions, and a critical level identified in Kherson. *Practical importance*. The developed methodology can be used to monitor and diagnose the state of industrial safety in regions, and to develop programmes for economic recovery and the strengthening of industrial potential. The proposed system of indicators provides a foundation for the further improvement of state regulatory mechanisms, the formation of regional security strategies, and the making of management decisions in the field of economic stability.

Keywords

industrial safety, economic security, indicator approach, assessment methodology, regional development, Black Sea region, integrated assessment, energy efficiency, industrial potential

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1 Introduction

Against the backdrop of deepening socioeconomic instability and the growth of technogenic, economic and national security risks, coupled with the prolonged impact of armed conflict on Ukrainian territory, ensuring an adequate level of industrial safety is becoming increasingly important. This is a key factor in ensuring the economic stability of regions in the face of growing internal and external challenges, particularly during and after periods of war. Currently, the absence of a unified methodological approach to forming a system of indicators for assessing industrial safety significantly complicates monitoring, risk analysis and informed management decision-making at the regional level. Existing methodologies are usually

fragmented and not sufficiently adapted to crisis and post-crisis conditions. In this context, the indicator approach is considered a promising tool for systematically covering key influencing factors, ensuring the assessment is comprehensive and representative, and creating a reliable basis for making effective strategic decisions to ensure regional industrial safety.

The methodological aspects of forming a system of indicators to assess industrial safety at a regional level are based on combining theoretical principles of economic security with applied analytical methods. Works by Mkhalitska and Tsvaih (2017), Sichyokno (2018) and Aleksandrova (2010) demonstrate the effectiveness of using integral and functional indicators to enable a holistic safety assessment approach. At the same time, Bohma (2016), Hnatenko (2021), Hbury (2018) and Pikhotskyi and Pikhotska (2022) emphasise that the production component is a key part of economic security and requires its own assessment system. A significant focus is placed on the regional specificity of the formation of the indicator system in the works of Ivanova and Malovychko (2019), Ovcharenko (2021) and Tkach (2015), which justify the necessity to adapt general approaches to the conditions of individual territories. In the context of instability and external threats, as evidenced by the works of Vashai and Doroshenko (2019), Kulish and Liadska (2019), the necessity for a flexible, dynamic and crisis-responsive indicator system is paramount. In view of the necessity to enhance the precision and legitimacy of industrial safety evaluation at the level of individual regions, the imperative for the enhancement of the prevailing system of indicators is becoming more pressing. The utilisation of standard macroeconomic indicators alone does not permit adequate consideration of local regional characteristics.

The purpose of the paper is to substantiate methodological approaches to the formation of a system of indicators for assessing industrial safety at the regional level, as well as to test the proposed methodology using the example of the Black Sea region of Ukraine.

2 Theoretical and Methodological Aspects for Developing a System of Indicators for Assessing Industrial Safety at the Regional Level

The establishment of an effective system for evaluating industrial safety at the regional level necessitates a robust theoretical and methodological foundation. This involves the analysis of the conceptual apparatus, the identification of scientific approaches to safety assessment, and the determination of the principles for constructing indicator systems. Industrial safety constitutes an integral component of the overarching security system of the economy and society. The primary objective of this component is to ensure the continuous, effective and safe functioning of production processes. It encompasses a range of measures and mechanisms designed to prevent accidents, incidents, man-made disasters and to minimise the consequences of such occurrences in production activities.

The industrial safety of the region is understood to be a dynamic state of the regional production and logistics environment. This is characterised by the ability to ensure the continuity and efficiency of the functioning of all components of the production chain, to preserve labour and material resources. This is achieved through the systematic use of indicators, as well as the implementation of organisational, technical, regulatory and administrative measures based on an integrative approach to the assessment and management of industrial risks. The level of industrial safety is an important indicator of the resilience of production systems to various internal and external threats, and also characterises the ability of industrial sectors to quickly recover and adapt in the face of dynamic economic and social challenges.

The indicator approach constitutes an effective tool in the system of assessing industrial safety at the regional level, as it allows for a comprehensive consideration of various aspects of production activities and the risks associated with them. The employment of an indicator approach, accounting for regional characteristics, facilitates the creation of an adaptive assessment model. This model ensures the accuracy and relevance of the analysis, thereby supporting the adoption of effective management decisions in the field of accident, incident and consequence prevention.

The establishment of a system of indicators for the assessment of industrial safety at the regional level is contingent upon the adherence to a series of methodological criteria that guarantee the scientific validity, comprehensiveness and functional adaptability of such a system. It is imperative to consider regional particularities, socio-economic, technical and environmental factors to ensure the relevance and accuracy of the indicators. Concurrently, the system must be capable of reflecting the multidimensional nature of industrial safety, facilitating operational monitoring and supporting the process of making informed management decisions in the context of regional risk management.

Table 1 sets out a series of indicators designed to reflect the multidimensional nature of industrial safety in the regions. The proposed list encompasses economic, technical and technological, socio-demographic and energy parameters that characterise both the general level of industrial development of the region and potential threats to the stable functioning of production systems on its territory.

TABLE 1 Characteristics of indicators for assessing industrial safety at the regional level

№	Indicator name	Characteristic of the indicators
1	Share of gross added value of the industry of the region in the national volume, %.	This indicator measures the region's economic activity, reflecting its contribution to the national industrial potential and determining its role in the production of the national industrial product.
2	Share of innovatively active enterprises in the industry of the region, %.	The indicator reflects the proportion of enterprises in the region's industrial sector that implement innovative changes (in technology, products, processes or organisation) relative to the total number of industrial enterprises.
3	Employment level in the industrial sector of the region, %.	This indicator reflects the socio-economic state of the region, the scale of industrial activity and the level of population involvement in the production sector, as well as the potential of labour resources to ensure the sustainable development of industry.
4	Degree of depreciation of fixed assets of industry, percent.	This is an integral indicator of the state of the region's technical and technological capabilities. It reflects the proportion of depreciated, obsolete or physically worn-out production assets in the fixed capital structure. It measures the level of depreciation and technological burden on the industrial sector, and is crucial for evaluating investment attractiveness, production productivity, innovative capacity, and economic security.
5	Share of high-tech products in the total volume of sold industrial products, percent.	The indicator plays a key role in quantifying the level of technological development of the region's production structure. It reflects the degree of innovative activity of enterprises in the industrial sector and characterises the intensity of technology transfer and the implementation of scientific research and development (R&D) results in the real economy.
6	Operating profitability of industrial enterprises, percent.	This is an indicator of the local industrial complex's ability to ensure the profitability of basic economic activities in the face of internal and external challenges.
7	Yield of main grain and leguminous crops, tons per 1 ha of harvesting area.	This indicator reflects the efficiency of agricultural land use and the level of technology used in agricultural production in the region.
8	Share of agricultural products in the total volume of gross added value (GVA) of the region, %.	This indicator reflects the degree to which the region is specialised in a given sector, given the importance of agriculture in its economic structure.
9	Energy intensity of industrial production (energy consumption per unit of output).	This indicator characterises the amount of energy resources consumed per unit of output, reflecting the technical condition of equipment, the energy efficiency of production processes, the innovativeness of technological solutions, and the sensitivity of enterprises to fluctuations in energy prices or crises in energy supply.

Source: developed by the author

To ensure a comprehensive and methodologically sound assessment of regional production security, Table 2 presents a system of characteristic values for the indicators. The defined threshold limits enable security levels to be identified for each indicator and their stimulating or destimulating effects to be taken into account. This provides an analytical basis for normalising the indicators and subsequently integrating the analysis of the state of production security at the regional level.

The developed system of indicators and their defined characteristic values form a coherent methodological framework for the practical application of the proposed approach to assessing regional production security. In order to verify the effectiveness and analytical capacity of the methodology, it is necessary to conduct empirical testing using real statistical data. The following section therefore presents an evaluation of the production security assessment methodology based on the system of indicators at the regional level, using the Black Sea region as a case study.

3 Testing the Methodology for Assessing Industrial Safety Using a System of Indicators at the Regional Level (by Example of the Black Sea Region)

The proposed methodology was tested using the Black Sea region as an example, including the Odesa, Mykolaiv and Kherson regions. The Black Sea region was chosen due to its strategic importance in economic, infrastructural and industrial contexts, and because of the presence of various types of industrial clusters. The proposed methodology was tested using the Black Sea region as a case study, covering the Odesa, Mykolaiv and Kherson areas. This region was chosen because of its strategic importance in economic, infrastructural and industrial contexts, and because of the presence of various industrial clusters. At the same time, the region remains vulnerable to complex risks, particularly military, environmental and technological ones. This necessitates a systematic approach to monitoring industrial safety and managing potential threats. This assessment is

TABLE 2 Characteristic values of the indicator values for assessing industrial safety at the regional level

No.	Indicator name, unit of measurement	Characteristic values of the indicator									
		$X^L_{critical}$	$X^L_{dangerous}$	$X^L_{no\ shift}$	X^L_{shift}	$X^L_{optimal}$	$X^R_{optimal}$	X^R_{shift}	$X^R_{no\ shift}$	$X^R_{dangerous}$	$X^R_{critical}$
1	2	3	4	5	6	7	8	9	10	11	12
Industrial safety											
1	Share of gross added value of the industry of the region in the national volume, %.	1	3	5	7	10	15	20	25	30	40
2	Share of innovatively active enterprises in the industry of the region, %.	1	2	3	5	7	10	15	20	25	30
3	Employment level in the industrial sector of the region, %.	10	20	30	40	50	60	70	80	85	90
4	Degree of depreciation of fixed assets of industry, percent.	5	10	15	20	30	40	50	60	70	80
5	Share of high-tech products in the total volume of sold industrial products, percent.	1	2	3	5	7	12	30	45	60	75
6	Operating profitability of industrial enterprises, percent.	1	3	4	5	6	10	20	30	40	60
7	Yield of main grain and leguminous crops, tons per 1 ha of harvesting area.	15	20	25	35	45	55	75	95	100	150
8	Share of agricultural products in the total volume of gross added value (GVA) of the region, %.	5	10	15	20	25					
9	Energy intensity of industrial production (energy consumption per unit of output).						≤0.2	0.2–0.3	0.3–0.4	0.4–0.6	>0.6

* L (left part) – for indicators that are stimulants, rationing is carried out according to the criteria of the left part;
R (right part) – for indicators that are disincentives, rationing is carried out according to the criteria of the right part.

Source: author's proposals for improving indicators and indicator values for rationing of the industrial safety in the regions.

based on a system of indicators developed as part of a theoretical and methodological framework for analysing industrial safety at a regional level.

Table 3 presents the distribution of gross added value of industry in Odesa, Mykolaiv and Kherson regions.

Assessing the gross industrial added value in the Odesa, Mykolaiv and Kherson regions makes it possible to distinguish between the regions' different levels of industrial safety and potential. The Odesa region demonstrates moderate industrial development, accounting for about 3–4% of the national gross added value, primarily due to activities in the food and light industries, as well as port infrastructure. However, the blockade of sea routes and logistical restrictions are reducing production activity, resulting in a low level of industrial safety. The Mykolaiv region, which has a traditional focus on shipbuilding and mechanical engineering, has suffered significant destruction to its industrial infrastructure as a result of the war. This has reduced its share of gross added value to between 2.5% and 3.5%, and put the region on the verge of dangerous levels of industrial safety. The prospects for recovery depend on the pace of post-war rehabilitation. The Kherson region is characterised by a critically low level of industrial development (gross added value of around 1.5–2%), a situation that has been further exacerbated by occupation, infrastructure destruction and the disruption of logistical connections. This has led to the near-complete collapse of industrial production, placing the region in a critical industrial safety zone and requiring comprehensive state support and investment to facilitate recovery.

Table 4 presents a comparison of the innovative activity of regions with a rating scale (1–30%).

Analysing the innovation activity of industrial enterprises in the Odesa, Mykolaiv and Kherson regions reveals significant differences in their potential and sustainability. The Odesa region is characterised by a share of innovation-active enterprises of about 9.3%, which corresponds to an intermediate

TABLE 3 Distribution of the industry gross added value in Odesa, Mykolaiv and Kherson regions

Region	Average share in gross added value of Ukraine (%)	Classification (by scale)	Key problems
Odesa	~ 3 – 4%	$X^{L}_{dangerous}$ / $X^{L}_{no\ shift}$	The share corresponds to the low or below-average industrial activity zone, characterised by a reduction in production output due to the blockade of seaports, logistical restrictions, reduced exports, and a lack of investment in the industrial sector.
Mykolaiv	~ 2.5 – 3.5%	$X^{L}_{dangerous}$	The region has suffered significant destruction to its industrial infrastructure, particularly in the shipbuilding sector. High military risk, the destruction of defence industry enterprises, the loss of sales markets and the outflow of personnel significantly limit the restoration of industrial potential.
Kherson	~ 1.5 – 2%	$X^{L}_{critical}$ / $X^{L}_{dangerous}$	Industrial activity is critically low. The occupation of part of the territory, the destruction of industrial facilities and transport infrastructure, the explosion at the Kakhovka hydroelectric power station, the disruption to the energy supply, and the evacuation of enterprises have resulted in the shutdown of most industrial facilities.

Source: calculated and interpreted by the author based on statistical data.

TABLE 4 Comparison of the innovative activity of regions with a rating scale (1–30%)

Region	Share of innovatively active enterprises, %	Category by scale	Key problems
Odesa	9.3%	$X^{L}_{optimal}$ / $X^{R}_{optimal}$	There is high potential, but vulnerability due to the ports, the blockade and the unstable logistics and lack of technological clusters.
Mykolaiv	9.5%	$X^{L}_{optimal}$ / $X^{R}_{optimal}$	The loss of infrastructure and enterprises due to war results in the halting of innovations due to the destruction of basic industries.
Kherson	≈ 5%	Corresponds X^{L}_{shift}	There was a weak industrial profile before the war, and the war and subsequent occupation completely halted the innovation process.

Source: calculated and interpreted by the author based on statistical data

level between the $X^{L}_{optimal}$ (7%) and $X^{R}_{optimal}$ (10%), and indicates a sufficient, but not regular level of innovation development. A favourable economic and geographical location, access to the Black Sea, and port infrastructure create the prerequisites for innovation logistics clusters. However, the blockade of the ports, the instability of the logistics sector, and institutional challenges limit the realisation of the technological potential. The Mykolaiv region, with an innovatively active enterprise share of about 9.5%, also belongs to the zone of basic innovation potential. However, large-scale infrastructure destruction, enterprise and personnel losses resulting from the war have decreased innovation dynamics. At the same time, preserving technical schools and residual resources creates the prerequisites for restoring innovative activity, provided strategic investment and infrastructure reconstruction are made. The Kherson region, with a share of about 5%, demonstrates low innovative activity, which before the war already corresponded to the limits of X^{L}_{shift} category; the war, occupation and destruction of engineering and logistics infrastructure practically stopped innovative processes, transferring the region to a zone of high risk of industrial safety.

Comparison of regions by indicator 3 “Employment level in the industrial sector of the region" is presented in Table 5.

Analysis of employment levels in the industrial sectors of the Odesa, Mykolaiv and Kherson regions indicates different levels of industrialisation and industrial safety. The Odesa region with an indicator of 16.2% falls into the $X^{L}_{dangerous}$ category, which reflects the low level of industrialization, the dominance of logistics and port-trade activities and limited involvement of the population in industrial production, which creates vulnerability to external economic shocks and requires stimulation of the development of industrial clusters. The Mykolaiv region with an employment level of 22.5% belongs to the $X^{L}_{dangerous}$/ $X^{L}_{unstable}$, demonstrating a decline in industrial potential due to the destruction of enterprises and infrastructure as a result of the war, but retains significant recovery potential under conditions of investment and reconstruction of industrial capacities. The Kherson region with a critically low employment level of 13.1% (category $X^{L}_{critical}$) has actually experienced systemic deindustrialisation due to occupation, destruction of infrastructure and loss of access to resources.

TABLE 5 Comparison of regions by indicator 3 "Employment level in the industrial sector of the region"

Region	Employment rate in industry, %	Category by scale	Key features
Odesa	16.2%	$X^{L}_{dangerous}$ (close to 20%)	It is characterised by a low degree of industrialisation, mainly due to its economic specialisation in ports and logistics. The industrial sector is structurally limited, dominated by auxiliary activities and comprising a small number of high-tech industries.
Mykolaiv	22.5%	$X^{L}_{dangerous}$ / $X^{L}_{unstable}$ (above 20%, less than 30%)	The region has a long-established industrial base in shipbuilding and mechanical engineering. However, the destruction of key industrial enterprises and infrastructure facilities during wartime has led to a significant reduction in industrial employment. Currently, the level of industrial recovery is unstable.
Kherson	13.1%	$X^{L}_{critical}$ (≈10 – 15%)	The region has undergone regular deindustrialisation due to prolonged occupation, the destruction of critical infrastructure (particularly energy infrastructure) and the loss of access to industrial and logistics resources. The industrial sector is in a state of near-complete degradation and employment therein is minimal.

Source: calculated and interpreted by the author based on statistical data about employment in the industry.

Comparison of regions by indicator 4 "Degree of depreciation of fixed assets of industry" is presented in Table 6.

Analysis of the degree of depreciation of fixed assets in the Odesa, Mykolaiv and Kherson regions' industry demonstrates the different technical degradation of regional capital and industrial safety risks. The Odesa region with an indicator of 50.5% belongs to the X^{L}_{shift} category, which indicates significant moral and physical depreciation of production assets, complicates productivity growth, inhibits innovation processes and reduces investment attractiveness; stabilisation requires targeted renewal of fixed assets focused on energy efficiency, digitalisation and modernisation of logistics. The Mykolaiv region with a depreciation level of 47.5% also belongs to the X^{L}_{shift}/ $X^{L}_{optimal}$ zone, but is closer to the lower limit of the category, which reflects high, but not critical degradation of industrial infrastructure and the potential for modernisation during the implementation of investment and state recovery programmes. The Kherson region with a critical indicator of 98.4% falls into the $X^{L}_{critical}$ category, which actually means a complete loss of industrial capital, most assets are decommissioned or obsolete, and the restoration of production activities is possible only through complete technological rehabilitation.

Table 7 presents a comparison of regions by the share of high-tech products in the total volume of sold industrial products.

Analysis of the proportion of high-tech products sold in the industrial sector in the Odesa, Mykolaiv and Kherson regions shows that the regions are critically underrepresented in high-tech sectors. The Odesa region with an indicator of 1.9% belongs to the $X^{L}_{dangerous}$ category, which reflects the structural innovation backwardness of the industry and the predominance of traditional industries (food and processing industries), despite its favorable logistics and infrastructure position. The Mykolaiv region with a share of 0.5% belongs to the $X^{L}_{critical}$ category and is characterised by a deep innovation crisis, historically powerful high-tech areas have not been restored, technological rehabilitation is absent, which increases the risk of further technological decline. The Kherson region with an indicator of 0.02%

TABLE 6 Comparison of regions by indicator 4 "Degree of depreciation of fixed assets of industry"

Region	Degree of depreciation of fixed assets in industry, %	Category by scale	Key features
Odesa	50.5	X^{L}_{shift} (≈50 %)	There is a noticeable level of wear and tear, indicating the intensive physical and moral degradation of capital assets. Some of the assets already require modernisation or replacement, which reduces production efficiency and increases the risk of technological failure.
Mykolaiv	47.5	X^{L}_{shift}/ $X^{L}_{optimal}$ (≈47–50 %)	There is high depreciation of fixed assets, but this has not yet reached critical levels. There is potential for investment in recovery, but without such support, accelerated technological lag is possible.
Kherson	98.4	$X^{L}_{critical}$ (≈98 %)	There has been almost complete degradation of industrial capital. Almost all fixed assets are either physically or morally obsolete, or out of order. In fact, the assets require complete reconstruction or total replacement.

Source: calculated and interpreted by the author based on statistical data.

TABLE 7 Comparison of regions by the share of high-tech products in the total volume of sold industrial products

Region	Share of high-tech products in the total volume of sold industrial products, %	Category by scale	Characteristics
Odesa	1.9%	$X^{L}_{dangerous}$	The level of high-tech production is very low. Traditional industries such as processing and the food industry prevail, and high-tech sectors have not really developed. This puts the country at risk of falling behind in global competition.
Mykolaiv	0.5%	below the $X^{L}_{critical}$	There is a critically low share of high-tech products. Despite its historically strong industrial base in shipbuilding and mechanical engineering, a lack of innovative modernisation has resulted in technological decline.
Kherson	0.02%	below the $X^{L}_{critical}$	There is a practical absence of a high-tech sector. The region is characterised by the complete degradation of its innovation infrastructure due to war, occupation, and the loss of its production potential.

Source: calculated and interpreted by the author based on statistical data

also belongs to the $X^{L}_{critical}$ category and has virtually no high-tech production, the war and occupation resulted in collapse of the innovation infrastructure, which requires a comprehensive reconstruction of the industry.

Comparison of regions by indicator 6 "Operating profitability of industrial enterprises" is presented in Table 8.

Analysis of the operating profitability of industrial enterprises indicates a sharply differentiated financial condition of the regions. The Odesa region with an indicator of 7.7% belongs to the $X^{R}_{optimal}$ category and demonstrates moderately stable profitability, which is due to a diversified economic structure and logistics and port advantages that compensate for the low level of the technological sophistication of the industry. The Mykolaiv region with the negative profitability of -10% falls into the $X^{L}_{critical}$ category, which reflects a deep financial crisis due to the destruction of infrastructure, partial shutdown of enterprises and disruption of export chains; the region requires systemic rehabilitation and investment support. The Kherson region with a profitability of -21% also belongs to $X^{L}_{critical}$ and is characterised by almost complete deactivation of the industrial sector due to the destruction of enterprises, occupation and loss of logistics capabilities. The restoration of economic activity requires comprehensive reconstruction of the industrial infrastructure, as well as priority state support.

Comparison of regions by indicator 7 "Yield of main grain and leguminous crops" is presented in Table 9.

Analysis of the yield of the main grain and legume crops indicates that the agricultural sectors of the regions are in a state of sharp differentiation. With an indicator of 28 dt/ha, the Odesa region belongs to the X^{L}_{shift} category and demonstrates a slight decrease in productivity due to limited access to modern equipment, material and technical resources and partial disruptions in logistics. However, agricultural production is maintained due to stable natural and climatic conditions and the availability of land resources. The Mykolaiv region with a yield of 22 dt/ha falls into the $X^{L}_{unstable}$ category, which reflects

TABLE 8 Comparison of regions by indicator 6 "Operating profitability of industrial enterprises"

Region	Operating profitability of industrial enterprises, %	Category by scale	Key features
Odesa	7.7%	$X^{R}_{optimal}$	The region demonstrates moderately stable profitability among industrial enterprises. Despite the dominance of traditional industries, operational efficiency is ensured by the presence of logistical advantages and a diversified economic structure.
Mykolaiv	-10%	below the $X^{L}_{critical}$	Negative profitability is evidence of the industrial sector's deep financial instability. This is due to significant infrastructure losses, enterprise shutdowns and the destruction of export chains as a result of the war. This situation requires systemic rehabilitation and external financial intervention.
Kherson	-21%	below the $X^{L}_{critical}$	A catastrophically low level of profitability signals an almost complete shutdown of industrial activity. A significant proportion of enterprises have been destroyed or are not functioning, and economic activity has been reduced to a minimum.

Source: calculated and interpreted by the author based on statistical data

TABLE 9 Comparison of regions by indicator 7 "Yield of main grain and leguminous crops"

Region	Yield of main grain and leguminous crops, %	Category by scale	Key features
Odesa	28	X^{L}_{shift}	There has been a slight decline in productivity due to limited access to machinery and resources and the partial disruption of logistics. However, agricultural production is supported by stable land resources.
Mykolaiv	22	$X^{L}_{unstable}$	Productivity has declined slightly due to limited access to machinery and resources, as well as partial disruption to logistics. However, stable land resources support agricultural production.
Kherson	10	$X^{L}_{critical}$	There has been significant degradation of agricultural land and limited access to fields due to occupation and hostilities. Yields are critically low, threatening the region's food security.

Source: calculated and interpreted by the author based on statistical data

a significant decrease in productivity due to the destruction of agricultural infrastructure, a shortage of labour and material and technical resources, the region needs to restore the agrotechnical facilities and invest in modernisation. The Kherson region with a critically low indicator of 10 dt/ha belongs to the $X^{L}_{critical}$ category, which is a consequence of significant land degradation, difficult access to fields due to occupation and active hostilities. The situation poses a serious threat to food security and requires systematic state support and the restoration of land use and agricultural infrastructure.

Comparison of regions by indicator 8 "Share of agricultural products in the total volume of gross added value (GVA) of the region" is presented in Table 10.

Analysing the proportion of agricultural products in the regions' gross added value indicates the different stages of development of the agricultural sector. The Odesa region with an indicator of 12% belongs to the $X^{L}_{no\ shift}$ category and is at the initial stage of stabilisation of agricultural production. Despite its favourable geographical location and well-developed transport infrastructure, the region needs to modernise its production facilities, improve its logistics and attract investment in order to increase the efficiency of its agricultural sector. The Mykolaiv region with a share of 18% falls into the X^{L}_{shift} category and demonstrates active development of agricultural production, which makes the agricultural sector one of the drivers of the economy; however, the consequences of the war and damage to the infrastructure remain a challenge that requires modernisation of enterprises and the introduction of modern agricultural technologies. The Kherson region with an indicator of 7% is classified as $X^{L}_{dangerous}$, which reflects a critically low level of development of the agricultural sector due to military actions, occupation and destruction of production infrastructure. Restoration requires significant investment, an updated technical fleet, and a personnel policy aimed at attracting qualified specialists back to the company.

Comparison of regions by indicator 9 "Energy intensity of industrial production (energy consumption per unit of output)" is presented in Table 11.

Comparison of regions by energy intensity of industrial production demonstrates significant disparities. The Odesa region with an indicator of approximately 0.25 conventional units belongs to the X^{L}_{shift} category, which indicates positive developments in the modernisation of technological processes and the implementation of energy-saving measures. The region's industrial sector is actively optimising resource use, reducing energy costs and increasing product competitiveness. There is also potential for the

TABLE 10 Comparison of regions by indicator 8 "Share of agricultural products in the total volume of gross added value (GVA) of the region"

Region	Share of agricultural products in the gross added value, %	Category by scale	Brief description of the situation
Odesa	12	$X^{L}_{no\ shift}$	The agricultural sector is beginning to stabilise, and there is potential for growth through infrastructure development and modernisation of production.
Mykolaiv	18	X^{L}_{shift}	The agricultural sector is experiencing active development and makes a significant contribution to gross added value. It is one of the region's key economic drivers.
Kherson	7	$X^{L}_{dangerous}$	The share of agricultural products is low due to military operations and occupation, which have had a negative impact on the agricultural sector.

Source: calculated and interpreted by the author based on statistical data.

TABLE 11 Comparison of regions by indicator 9 "Energy intensity of industrial production (energy consumption per unit of output)"

Region	Energy output (conventional units, approximate estimate))	Category by scale	Substantiation
Odesa	0.25	X^{L}_{shift} (0.2–0.3)	Production is relatively energy-efficient thanks to the partial modernisation of technological processes and the introduction of energy-saving solutions. Industrial enterprises are actively working on optimising resources, which ensures a positive trend in reducing energy intensity.
Mykolaiv	0.35	$X^{L}_{no\ shift}$ (0.3–0.4)	The average level of energy intensity is due to the partial restoration of industrial potential following destruction. Technological facilities require updating and energy consumption remains higher than optimal due to outdated equipment and insufficient implementation of energy efficiency measures.
Kherson	0.50	$X^{L}_{dangerous}$ (0.4–0.6)	High energy intensity is caused by the significant destruction of industrial infrastructure, reduced production efficiency and a lack of resources for modernisation. Enterprises are operating in emergency mode, which increases energy consumption. The lack of stability and investment also slows down the introduction of energy-saving technologies, threatening production safety and the economic stability of the region.

Source: calculated and interpreted by the author based on statistical data.

further implementation of innovative technologies. The Mykolaiv region with an average level of energy intensity (approximately 0.35 conventional units, category X^{L}_{shift}) is characterised by partial restoration of industrial potential after destruction, however, the presence of outdated equipment and insufficient implementation of energy-efficient solutions keep energy consumption at an elevated level; targeted investments in modernisation and energy management are required to reduce the indicator. The Kherson region demonstrates the highest energy intensity (approximately 0.50 conventional units, $X^{L}_{dangerous}$) due to the destruction of industrial infrastructure, reduced technological efficiency and lack of resources for modernisation; enterprises operate in emergency mode, which increases energy consumption and threatens industrial safety. The differences between regions reflect the technical state of the industry, economic development, the investment climate, and the consequences of military operations. This emphasises the need for comprehensive measures to modernise production, optimise energy consumption, and introduce modern technologies to increase the efficiency and safety of the industrial sector.

To enable a clear comparison and comprehensive assessment of industrial safety in the Black Sea region, the following table reflects the values of key indicators for the Odesa, Mykolaiv and Kherson regions. It also shows how these regions are categorised on a certain scale, as well as the corresponding point distribution. This will make it possible to summarise the quantitative data and carry out a qualitative interpretation of the state of industrial and agricultural safety in the regions.

Table 13 presents a comprehensive summary of the assessment of the industrial safety level in the Odesa, Mykolaiv and Kherson regions, based on an individual analysis of each indicator.

A comprehensive assessment of industrial safety levels in the Odesa, Mykolaiv and Kherson regions of Ukraine's Black Sea region reveals significant differences in the structure and efficiency of their industrial and agricultural sectors. With an average score of 4.2, the Odesa region is characterised by a low but relatively stable level of safety, requiring modernisation of production facilities and increased investment activity. The Mykolaiv region (average score: 3.5) is characterised by a low and unstable level of security due to limited innovation and the partial consequences of external factors hindering the restoration of production potential. The Kherson region, with an average score of 1.64, has a critically low level of security. Infrastructure degradation and the wear and tear of industrial facilities, coupled with regular production disruptions, pose a catastrophic risk to the region's economic stability. Thus, the assessment indicates that regionally differentiated measures are needed to modernise and support innovation, as well as to increase the efficiency of production processes, in order to ensure the stability of the economy in the Black Sea region.

4. Conclusions

The results of the regional-level industrial safety assessment, carried out using a developed system of indicators, confirmed the presence of deep

TABLE 12 Assessment of the industrial safety level in the regions according to key indicators

No.	Indicator	Odesa region (value)	Category	Points	Mykolaiv region (value)	Category	Points	Kherson region (value)	Category	Points
1	Share of gross added value of the industry of the region, %	~3.5%	$X^L_{dangerous}$ / $X^L_{no\ shift}$	2.25	~3%	$X^L_{dangerous}$	2	~1.75%	$X^L_{critical}$/ $X^L_{dangerous}$	1.4
2	Share of innovatively active enterprises, %	9.3%	$X^L_{optimal}$ / $X^R_{optimal}$	5.8	9.5%	$X^L_{optimal}$ / $X^R_{optimal}$	5.8	~5%	X^L_{shift}	4
3	Employment level in the industry %	16.2%	$X^L_{dangerous}$	1.6	22.5%	$X^L_{dangerous}$/ $X^L_{unstable}$	2.3	13.1%	$X^L_{critical}$	1.3
4	Degree of depreciation of fixed assets of industry, %	50.5%	X^L_{shift}	3.95	47.5%	X^L_{shift}/ $X^L_{optimal}$	4.25	98.4%	$X^L_{critical}$	0.1
5	Share of high-tech products, %	1.9%	$X^L_{dangerous}$	1.9	0.5%	below the $X^L_{critical}$	0.5	0.02%	below the $X^L_{critical}$	0.02
6	Operating profitability, %	7.7%	$X^R_{optimal}$	5.4	-10%	below the $X^L_{critical}$	0.5	-21%	below the $X^L_{critical}$	0
7	Yield of main grain and leguminous crops, dt/ha	28	X^L_{shift}	4.0	22	$X^L_{unstable}$	3.0	10	$X^L_{critical}$	1
8	Share of agricultural products in the total volume of gross added value, %	12	$X^L_{no\ shift}$	5.4	18	X^L_{shift}	7.6	7	$X^L_{dangerous}$	3.4
9	Energy intensity of industrial production	0.25	X^L_{shift}	7.5	0.35	$X^L_{no\ shift}$	5.5	0.50	$X^L_{dangerous}$	3.5

Source: calculated by the author

TABLE 13 Comprehensive assessment of the industrial safety level

Region	Total points (maximum 90)	Average point (maximum 10)	Level of industrial safety (assessment)
Odesa	37.8	4.2	**Low level of industrial safety.** The region is characterised by significant structural imbalances in industry and agriculture. Although the indicators of innovation activity and operating performance are approaching optimal levels, the high degree of depreciation of fixed assets and the limited share of high-tech products indicate the risk of technological backwardness. Targeted measures are required to modernise production facilities and increase energy efficiency in the industrial safety system.
Mykolaiv	31.45	3.5	**Low level of industrial safety with signs of instability.** The region has limited potential for the stable development of industry and agriculture. The share of high-tech products remains minimal, operating performance is negative and the energy intensity of production is moderately high. While there has been some stabilisation in the agricultural sector, the preservation of structural and technological problems requires the active implementation of innovative solutions and the modernisation of production processes.
Kherson	14.72	1.64	**Critical level of industrial safety.** The region is characterised by frequent disruption to the functioning of the industry and agricultural sectors: a critically high degree of depreciation of fixed assets; negative operating performance; excessive energy intensity of production; and low yield, share of agricultural products in gross added value, and indicators. This situation indicates a high risk of technological and economic destabilisation, requiring urgent, radical measures to restore production capacity, modernise infrastructure, and introduce innovative technologies.

Source: calculated by the author

structural problems in Ukraine's Black Sea region. A comprehensive analysis of nine key indicators in the Odesa, Mykolaiv and Kherson regions revealed significant differences in risk manifestation intensity, innovative activity levels, the technical condition of production facilities, and the efficiency with which the industrial and agricultural sectors function.

The proposed system of indicators is flexible and adapted to the statistical capabilities of the regional level. It takes into account the current socio-

economic challenges, including technogenic, energy and infrastructure risks. Its practical implementation enables the monitoring, diagnosis and forecasting of industrial safety levels, as well as providing a basis for management decisions at state and regional policy levels. The indicator approach enables the level of safety to be measured quantitatively and provides a qualitative interpretation of the identified threats. This creates a basis for targeted management decisions aimed at stabilising the situation in regions affected by military conflict. To increase industrial safety in unstable conditions, a comprehensive state policy is needed that supports the reconstruction of industrial infrastructure, stimulates innovation, improves management processes, and adapts the security system to crisis management conditions.

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