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Comprehensive Assessment of the Sustainable Development Level of Chemical Industry Enterprises and Econometric Modeling of the Factors Influencing It

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Abstract: The article observes the positive dynamics of sustainable development indicators at enterprises within the Uzkimyosanoat JSC system for 2021–2025. Taking into account the characteristics of high capital intensity, dependence on raw materials and energy, and export orientation inherent in the chemical industry, a multi-factor economic potential model has been developed based on the interdependence of production (P), financial (F), innovative (I), human resources (H), and marketing-logistics (M) blocks. The developed multi-factor economic potential model enriches the theory of evaluating the efficiency of chemical industry enterprises with new content. It takes the evaluation beyond the scope of resource or result categories, substantiating it as a scientific and methodological approach that allows for assessment based on the proportionality and harmony of five interconnected structural blocks at the level of the industry holding. Furthermore, it comprehensively assesses the impact of economic, environmental, and institutional factors on the sustainable development of enterprises, identifies the main factors ensuring sustainable development in the activities of enterprises within the Uzkimyosanoat JSC system, and scientifically substantiates their interdependence based on econometric analysis methods.

Key words: Capital intensity, chemical industry, integrated system, integral assessment algorithm, economic, resource-energy, environmental, institutional blocks, automated management, monitoring systems.

Introduction. The chemical industry is extremely important for the country's economic development, as it is a key sector in the development of agriculture, energy, pharmaceuticals, and construction, as well as in the production chain. Currently, reforms are being carried out in the Republic of Uzbekistan to develop the chemical industry, modernize existing chemical production enterprises, increase production volumes and expand the range of chemical products, reduce the state share in chemical industry enterprises and gradually privatize them, as well as deepen the product processing process.

By Decree of the President of the Republic of Uzbekistan No. PP-388 dated October 10, 2022, "On Approval of the Targeted Program for the Strategic Development of the Chemical and Gas Chemical Industry," the creation of the "Navoi Chemical Technopark," "Fergana Chemical Technopark," and "Cheroqoqaldoq" technological clusters was established. The implementation of 44 investment projects for the development of the chemical industry is planned for 2022-2027[1]. Through this, nearly 4,000 new jobs will be created in our country, and the production volume of various high value-added chemical industry products will be increased.

At the same time, the widespread implementation of the "green economy," decarbonization, ESG principles, and resource-saving production concepts in the global economy makes ensuring the sustainable development of chemical industry enterprises one of the priority tasks. Today, chemical industry enterprises are characterized by a number of problems related to high energy intensity, strong dependence on raw materials, increased environmental pressure, high production costs, and technological obsolescence. In particular, the chemical industry is one of the sectors generating a significant portion of global industrial waste and greenhouse gas emissions. Therefore, in developed countries, special attention is paid to ensuring the sustainability of enterprises through the introduction of energy-saving technologies, the digitalization of production processes, the use of circular economy principles, and the improvement of environmental management systems.

The formation of modern scientific approaches to sustainable development at chemical industry enterprises is primarily explained by the industry's high resource intensity and environmental impact. While traditional industrial management focuses primarily on economic indicators such as production volume, production costs, profit, and profitability, at the current stage, these criteria are insufficient to assess the sustainability of an enterprise. This is because the economic result of a chemical industry enterprise is often directly linked to the consumption of raw materials and energy resources, the volume of waste, the level of environmental safety, the reliability of technological processes, and the quality of corporate governance. Therefore, in modern scientific views, the sustainable development of chemical industry enterprises is interpreted through the chain of "economic result - resource consumption - environmental impact - management quality." In this chain, the economic result reflects the enterprise's market activity, revenue, profit, and profitability, while resource consumption indicates the efficiency of the production process related to energy and raw materials. Environmental impact is assessed by the environmental burden of production and the possibility of reducing waste and emissions. The quality of management is manifested in the integration of these areas

into a single strategic system, the strengthening of internal control, and the justification of long-term development decisions.

The sustainable development of chemical industry enterprises is a multifactorial economic process, the formation of which is directly dependent on the internal production potential of the enterprise, its financial condition, the level of resource utilization, opportunities for technological renewal, the consistency of environmental safety measures, and the quality of institutional management. These factors do not exist in isolation from each other, but rather act as an interacting system. Therefore, when assessing the sustainable development of chemical industry enterprises, it is necessary to focus not on the individual results of specific indicators, but on the functional dependence and overall balance between them.

Literature review. According to Michael Porter's views on developing the chemical industry and attracting innovations to this sector, global cooperation is essential for a successful climate change policy. However, firms and governments are less likely to support strict regulations if they hinder their economic opportunities. Understanding how these policies affect innovation will help policymakers create incentive structures or support tools that target the most affected sectors, such as the chemical industry, making their policies more economically and politically viable. Through this analysis, we seek to learn more about the Porter hypothesis in high-polluting industries and how policymakers can create comprehensive policies to comply with environmental goals[2]-[3].

Issues regarding the sustainable development of chemical industry enterprises, the efficient use of resources, and industrial modernization have been extensively researched. In particular, Sergey Glazyev and Abel Aganbegyan put forward the idea regarding industrial policy and investment sustainability that "technological systems have the ability to improve, and the efficiency of the production facilities that operate them increases over time"[4]. According to Alexander Tatarkin, "the most active and dynamic group of high-tech industries will develop—that is, material production based on rapidly updating and increasingly complex technologies, as well as so-called 'soft' technologies, which include software development, system integration, consulting, education, and others." This approach will allow the Urals to maintain its industrial orientation, but it will be a different type of industry focused on high-level intellectual enrichment and the production of new competitive products. In the works of Boris Panshin and Andrey Sokolov, the impact of digitalization technologies on industrial efficiency is substantiated[5].

Research methodology. The article critically reviews existing theoretical approaches to assessing the economic potential of industrial enterprises and scientifically substantiates their limitations in a highly capitalized and complex sector like the chemical industry. In particular, while traditional approaches primarily assess economic potential based on production capacity, financial results, or resource volume, they do not encompass technological, innovative, and marketing factors at the enterprise and industry levels as an interconnected system. Particularly in the context of a sectoral holding like JSC "Uzkimyosanoat," in order to fully reveal the true essence of economic potential, a multi-factor economic potential model is developed for the first time. This model is based on the interdependence of production (P), financial (F), innovative (I), human resources (H), and marketing-

logistics (M) blocks, taking into account the chemical industry's inherent high capital intensity, strong dependence on raw materials and energy resources, export orientation, and ongoing transformation processes. This model allows for a comprehensive assessment of economic potential not merely through individual indicators, but as a mutually integrated system. To comprehensively assess the sustainable development level of chemical industry enterprises, the goal was set to form a system of indicators covering economic directions. Between 2021 and 2025, positive dynamics in sustainable development indicators were observed across the enterprises within the JSC "Uzkimyosanoat" system. A conceptual model for assessing the sustainable development level of a chemical industry enterprise is presented. The model systematizes 16 key indicators covering the economic, environmental, and institutional directions of the enterprise's activities. Based on these indicators, a comprehensive assessment of the enterprise's sustainable development status is conducted.

Analysis and results. Taking into account the high capital intensity inherent in the chemical industry, its strong dependence on raw materials and energy resources, its export orientation, and the transformation processes within the sector, a multifactorial economic potential model based on the interdependence of production (P), financial (F), innovation (I), human resources (H), and marketing-logistics (M) blocks was developed for the first time. This model allows for a comprehensive assessment of economic potential not merely through individual indicators, but as a mutually integrated system.

An important aspect of the proposed approach is that economic potential is interpreted not as a static, but as a dynamic and systemic category. That is, economic potential is not just the sum of available resources, but is formed through their mutual harmony, proportionality, and effective management. In this context, while each block performs an independent function, it also ensures overall efficiency in interconnection with the other blocks. For example, if production capacity is high but financial stability or human resource potential is insufficiently developed, the efficiency of utilizing the overall economic potential is limited; conversely, if financial potential and export markets are strong but the technological base and innovation potential are weak, a decline in long-term competitiveness is observed.

Within the model, a new approach to assessing economic potential was proposed by separating the innovation and marketing-logistics blocks as independent structural components. This is especially important in the context of the chemical industry, which is undergoing transformation under the influence of ESG requirements and the principles of the "green economy." In a modern competitive environment, the efficiency of an enterprise is determined not only by production results, but also by innovative activity, the stability of logistics chains, and the level of integration into markets.

The practical significance of this model lies in the fact that it enables a comprehensive assessment of economic potential at the level of an industry holding such as JSC "Uzkimyosanoat," the identification of structural imbalances, and the improvement of management decision-making efficiency. In particular, by assessing the level of development of each block, it is possible to identify the areas of weakness

within the enterprise or industry, and on this basis, targeted measures can be developed.

Thus, the multifactorial economic potential model proposed in the dissertation enriches the theory of evaluating the efficiency of chemical industry enterprises with new content. It was substantiated as a scientific and methodological approach that takes the evaluation out of the confines of resource or result categories, allowing it to be assessed based on the proportionality and harmony of five interconnected structural blocks at the industry holding level.

It provides a comprehensive assessment of the impact of economic, environmental, and institutional factors on the sustainable development of enterprises, identifies the main factors ensuring sustainable development in the activities of enterprises within the JSC "Uzkimyosanoat" system, and scientifically substantiates their interdependence based on econometric analysis methods.

Furthermore, to assess the level of sustainable development of chemical industry enterprises, a scientific-methodological approach was proposed based on systematizing 16 indicators into 4 functional blocks—economic, resource-energy, environmental, and institutional directions—and merging them into a single integrated assessment system (Fig. 1).

The main advantage of the model is that, alongside financial results, it also takes into account resource utilization efficiency, environmental safety, and the quality of corporate governance.

As a result, the proposed model serves to comprehensively assess the level of sustainable development of chemical industry enterprises and ensure their long-term competitiveness.

To comprehensively assess the level of sustainable development of chemical industry enterprises, a system of indicators covering economic directions was formed.

Table 1

**Sustainable development indicators of enterprises within the JSC
"Uzkimyosanoat" system**

Year	Profitability (%)	Battery usage (%)	Energy Capacity (kWh/t)	Waste recycling (%)	ESG rating (score)
2021	9,2	64	1,85	24	38
2022	11,4	68	1,76	29	46
2023	13,8	74	1,62	35	57
2024	16,5	79	1,47	43	69
2025	18,1	84	1,35	51	78

Based on an improved methodological approach for comprehensively assessing the sustainable development level of JSC "Uzkimyosanoat," an algorithm was developed that integrates energy intensity, profitability, production capacity utilization, waste recycling share, and ESG levels. Furthermore, the enterprise's sustainable development level was evaluated using the CSDI (Comprehensive Sustainable Development Index) (Figure 1).

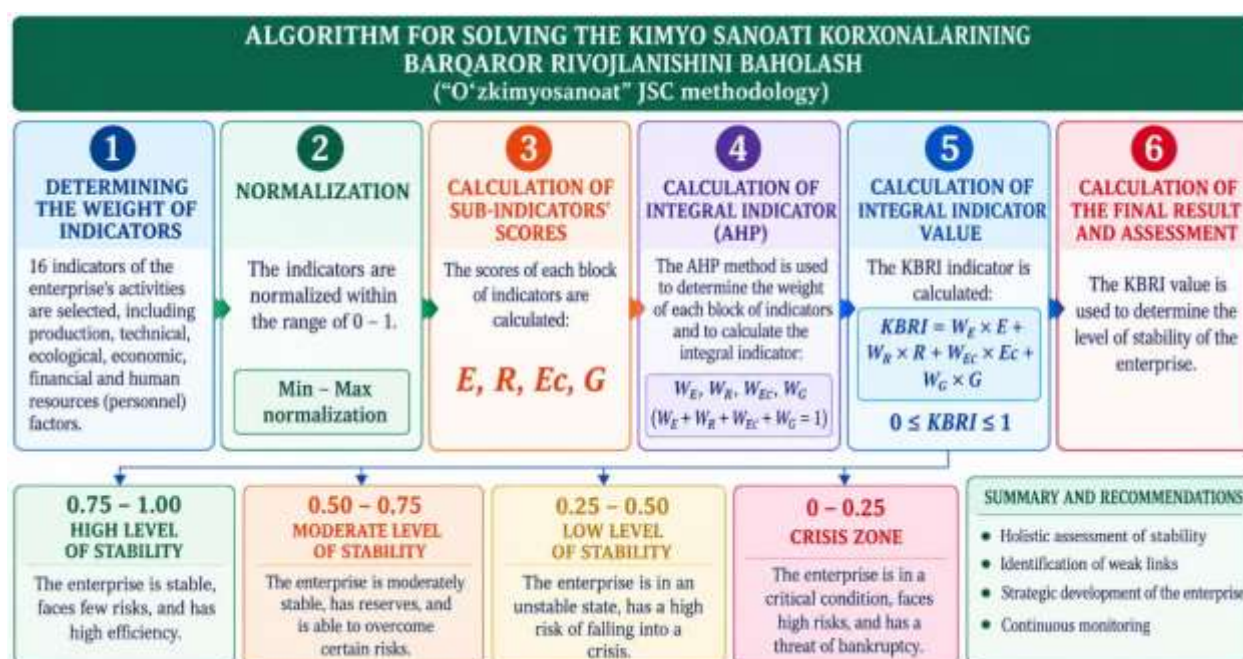


Figure 1. "Algorithm for the integral assessment of the sustainable development level of chemical industry enterprises (the case of JSC 'Uzkimyosanoat')"

According to the data in Table 5, positive dynamics of sustainable development indicators were observed at the enterprises of the "Uzkimyosanoat" JSC system in 2021–2025. In particular, the profitability rate increased from 9.2 percent to 18.1 percent, and the capacity utilization rate increased from 64 percent to 84 percent. At the same time, energy intensity decreased from 1.85 kWh/t to 1.35 kWh/t, indicating an improvement in resource efficiency.

Additionally, the share of waste recycling increased from 24 percent to 51 percent, and the ESG score increased from 38 to 78 points. This indicates that the implementation of environmental responsibility and corporate governance principles at the enterprises is consistently improving. Overall, the dynamics of the indicators confirm the strengthening of sustainable development factors at chemical industry enterprises.

Figure 1 shows a conceptual model for assessing the sustainable development level of a chemical industry enterprise. The model systematizes 16 key indicators across the economic, environmental, and institutional dimensions of the enterprise's activities. Based on these indicators, a comprehensive assessment of the enterprise's sustainable development status is conducted.

When calculating the SDI (Sustainable Development Index), it is important to determine the degree of impact the indicators have on sustainable development. To this end, the weight coefficients of the main indicators were determined based on the AHP method, and their share in the integral index was established.

Table 2

Weighting coefficients for sustainable development indicators of JSC "Uzkimyosanoat" enterprises (based on the AHP method)

Indicator	Symbol	Vazn
Profitability	X1	0,30

Indicator	Symbol	Vazn
Capacity utilization	X2	0,25
Energy capacity	X3	0,20
Waste recycling	X4	0,15
ESG level	X5	0,10
Total		1,00

According to the table data, the highest weight is assigned to the profitability indicator (0.30), demonstrating the primary importance of economic efficiency in sustainable development. Additionally, the capacity utilization rate (0.25) and energy intensity (0.20) account for a high share, confirming the significance of resource and energy factors. Waste recycling (0.15) and the ESG level (0.10) characterize environmental and institutional factors. The results indicate that economic and resource-energy factors play a leading role in ensuring the sustainable development of chemical industry enterprises.

Formula for normalizing indicators:

$$N_i = \frac{X_i - X_{min}}{X_{max} - X_{min}}$$

Calculation of the CSDI index based on the indicator normalization formula:

$$KBRI = 0,30 * X_1 + 0,25 * X_2 + 0,20 * X_3 + 0,15 * X_4 + 0,10 * X_5 \quad (1.1)$$

(where Xi are the normalized values)

Table 3

CSDI index calculation results

Year	CSDI	Normal range	Stability level
2021	0,00	0,00 – 0,25	Crisis zone
2022	0,22	0,00 – 0,25	Crisis zone
2023	0,53	0,50 – 0,75	Sustainable development
2024	0,81	0,75 – 1,00	High sustainable development
2025	1,00	0,75 – 1,00	High sustainable development

According to the CSDI index calculation results, sustainable development indicators at the enterprises within the Uzkimyosanoat JSC system have consistently improved over the 2021–2025 period. Specifically, the index value increased from 0.00 in 2021 to 1.00 in 2025. As a result, the enterprises transitioned from a crisis state in 2021–2022 to a sustainable development phase in 2023, achieving a high level of sustainable development in 2024–2025. This is attributed to increased economic efficiency, improved resource and energy indicators, strengthened environmental responsibility, and the widespread implementation of ESG principles.

Conclusion. Based on the analysis results, the SDI (Sustainable Development Index) was substantiated as an effective assessment tool that allows for a comprehensive assessment of the level of economic, resource-energy, environmental, and institutional development of chemical industry enterprises, the quantitative determination of their sustainability status, and the categorization of enterprises by

sustainability level. This forms the scientific and methodological basis for making management decisions to ensure sustainable development.

Based on the identified problems, management measures aimed at resource conservation, environmental modernization, improving ESG management, and developing innovative and investment activities will be developed. As a result, the sustainable development of enterprises will be ensured by improving their economic efficiency, resource utilization, environmental safety, and the quality of corporate governance.

The modernization of chemical industry enterprises and the development of cluster-type cooperation among them will have a multifaceted positive impact on the country's economy. Industrial cooperation unites producing entities (e.g., Navoiyazot JSC, Ferganaazot JSC, and small chemical enterprises) and allows them to create a coordinated production chain. The development of chemical industry enterprises, which are the drivers of Uzbekistan's economy, has a multifaceted positive impact on the regional economy and the industrial chain.

Presidential decrees aimed at the further reform and financial recovery of chemical industry enterprises and the expansion of high-value-added chemical production define the task of the phased implementation, by 2024, of automated management and monitoring systems (ERP and other integrated automated control systems) covering production and management processes, financial and economic activities, and the sale and delivery of goods at enterprises within Uzkimyosanoat JSC. The creation of a separate project and responsible positions for the implementation of the ERP system within the Company, the integration of information flows into a single platform, and the ongoing work to form an "Automated Information Analysis Center" confirm the institutional need for digital management mechanisms in the industry.

We believe that the sustainable development of enterprises should be achieved not only by increasing production volumes or financial indicators, but also by ensuring the interdependence of economic efficiency, environmental balance, and institutional management.

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