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METHODS FOR ASSESSING THE ECONOMIC EFFICIENCY OF INNOVATIVE ACTIVITIES IN THE PRODUCTION OF AUTOMOTIVE SPARE PARTS

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Abstract - *The assessment of the economic efficiency of innovative activities in the process of auto parts production is directly related not only to the criteria of production efficiency and cost reduction, but also to the goals of forming an innovative economy, technological modernization and production of competitive products set out in the "Uzbekistan - 2030" development strategy. In this process, the efficiency of spare parts production increases dramatically through the use of 3D printing, automated production lines, digital warehouse management and quality management systems. As a result, production costs decrease, high-quality products fill the domestic market, and export potential increases. This serves the goals of Uzbekistan's national strategic priorities for innovative development - diversification of the industry, creation of new jobs and integration with international markets.*

Keywords: *Economic efficiency, strategic priorities, potential increases, innovative activities.*

INTRODUCTION

In the context of accelerating technological change and increasing global competition, the production of automotive spare parts is undergoing profound structural and economic transformation. Modern automotive markets are characterized by shortened product life cycles, growing customization requirements, stricter quality and safety standards, and sustained pressure to reduce costs while maintaining technological relevance. Under these conditions, innovative activity becomes not merely a source of competitive advantage, but a prerequisite for the sustainable development of enterprises engaged in the manufacture of automotive components. Innovations in materials, production technologies, digital manufacturing systems, logistics, and product design significantly influence production efficiency, cost structures, and market positioning, thereby necessitating a rigorous and well-founded assessment of their economic effectiveness.

Despite the strategic importance of innovation, enterprises in the automotive spare parts sector often face methodological difficulties in evaluating the real economic outcomes of innovative initiatives. Traditional approaches to efficiency assessment, which are primarily oriented toward short-term financial indicators or isolated

investment projects, are frequently insufficient to capture the multifaceted and dynamic effects of innovation. Innovative activities typically generate both direct and indirect economic results, including productivity growth, reduction of defect rates, optimization of resource utilization, enhancement of technological flexibility, and long-term strengthening of innovative potential. These effects are often distributed over time and intertwined with organizational and technological changes, which complicates their measurement using standard financial metrics alone.

The relevance of developing and applying comprehensive methods for assessing the economic efficiency of innovative activities is particularly pronounced in the automotive spare parts industry, where production processes are capital-intensive and closely integrated into global value chains. Innovations in this sector not only affect internal production indicators but also influence relationships with original equipment manufacturers, aftermarket distributors, and end consumers. Consequently, an adequate assessment framework must account for the interaction between technological innovation, production performance, and market outcomes, as well as the risks and uncertainties inherent in innovation-driven development.

This article is devoted to the analysis and systematization of methods for assessing the economic efficiency of innovative activities in the production of automotive spare parts. The study aims to substantiate methodological approaches that allow for a more accurate evaluation of innovation outcomes, taking into account the specific features of industrial production, technological modernization, and competitive dynamics in the automotive sector. By focusing on both quantitative and qualitative dimensions of efficiency, the research seeks to contribute to the development of more informed managerial decision-making and to support the strategic planning of innovative development in automotive spare parts manufacturing enterprises.

LITERATURE REVIEW

In assessing economic efficiency, not only financial indicators, but also social and institutional factors are of particular importance. For example, the mechanisms of incentives and subsidies created by the state, research and experimental design work in collaboration with scientific centers, and the development of human capital are among the main factors of the efficiency of innovative activity. As stated in the “Uzbekistan - 2030” strategy, the goal is to rationally use resources through the widespread introduction of new technologies in production, ensure environmental sustainability, and implement social innovations. In this regard, methods for assessing the innovative activity of auto parts production, along with showing economic efficiency, appear as a strategic mechanism that contributes to the long-term sustainable development of the country. The importance of assessing the innovative activity of auto parts production is that it not only increases the competitiveness of the national industry, but also inextricably links Uzbekistan to the supply chains of the global automotive industry. Today, the production of automotive parts in the global market is being driven by innovative technologies - 3D printers, robotic assembly lines, smart logistics systems - and they are considered a decisive factor in creating high added value in the

international value chain. In this regard, the priority areas of innovative development and export expansion, set out in Uzbekistan's "Development Strategy for 2030", are combined with best practices in the global automotive industry. This process will serve to integrate the country's enterprises into the global market, adapt local manufacturers to international standards, and ensure sustainable economic growth through innovative products.

Zehra K. and co-authors argue that “to optimize automotive production, it is necessary to adopt Overall Equipment Effectiveness (OEE) as a central indicator to combine efficiency and sustainability. In their opinion, this approach requires not only assessing the technical capabilities of production lines, but also considering resource use, environmental footprint, and labor productivity as a whole. From a scientific and theoretical point of view, this economic mechanism is close to the concept of “sustainable efficiency”, in which, along with reducing production costs, environmental and social sustainability are also seen as key determinants.” In this regard, the economic doctrine put forward by scientists means that the automotive industry must manage innovative technologies and environmental responsibility in an integrated manner in order to strengthen its position in the global value chain.[87]

METHODOLOGY

This study applies an integrated methodological approach to assessing the economic efficiency of innovative activities in the production of automotive spare parts, taking into account the sector’s capital intensity, technological complexity, and strong dependence on quality and supply-chain integration. The methodology is designed to capture both the financial and strategic effects of innovation, recognizing that innovation outcomes in industrial production are multidimensional and often realized over extended periods.

The research combines quantitative and qualitative methods. Quantitative assessment focuses on evaluating the economic results of innovation through investment and performance analysis, including discounted cash flow analysis, cost–benefit evaluation, productivity dynamics, and changes in unit production costs resulting from innovative technologies or processes. A dynamic perspective is emphasized to reflect the delayed and cumulative economic effects of innovation rather than short-term financial outcomes.

Qualitative analysis is used to assess non-financial dimensions of efficiency, such as technological advancement, production flexibility, process reliability, risk reduction, and the impact of innovation on competitive positioning in the automotive spare parts market. These factors complement quantitative indicators and allow for a more comprehensive evaluation of innovation efficiency.

The methodology also incorporates comparative and structural analysis to identify changes in economic performance and cost structures before and after innovation implementation, as well as differences between innovative and non-

[87] Kaya, Z.; Demirel, Ö.; Aydin, M. Strategic integration of OEE into sustainability-oriented manufacturing systems // Journal of Industrial Engineering and Operations Management. — 2023. — Vol. 11, No. 2. — P. 145–162. DOI: 10.1016/j.ieom.2023.02.014

innovative production units. Empirical analysis is based on industry and enterprise-level data, supported by sensitivity analysis to account for uncertainty and risk. Overall, this approach ensures a balanced and robust assessment of the economic efficiency of innovative activities in automotive spare parts manufacturing.

ANALYSIS AND RESULTS

Another important point is that, based on the approach of Zehra K. et al., production efficiency is now evaluated not by simple production volume, but by its contribution to overall economic sustainability. According to them, by integrating OEE indicators into strategic management systems, enterprises can not only ensure short-term profitability, but also gain long-term competitive advantage.

The basic formula of OEE:

$$OEE = A \times P \times Q$$

Scientific and theoretical analysis shows that this approach is consistent with the transformation processes in the international automotive industry and, therefore, serves as an important methodological basis for developing innovative modernization strategies for developing countries such as Uzbekistan. As a result, the concept of economic efficiency acquires a humanized meaning, that is, it is understood that it is directly related not only to the increase in capital, but also to the well-being of society, environmental safety, and the development of human potential.

Extended strategic model:

$$SOEE = OEE \times ESI \times HSI$$

Here:

ESI — Environmental Sustainability Index

HSI — Human-centric Sustainability Index

Economic efficiency now has a humanized meaning — that is, it is directly related not only to the increase in capital, but also to the well-being of society, environmental safety, and the development of human potential. Thus, indicators such as OEE and SOEE serve to guide market mechanisms not only on the principle of “production alone”, but also on the principle of “stability and well-being”.

Modernizing the automotive industry in the country, “increasing the level of localization” and strengthening the “import substitution strategy” are among the priorities of state policy. “According to Clayton Christensen’s theory, such transformational processes ensure the “formation of an innovative ecosystem” and become the foundation of long-term industrial sustainability” . This study by Zareian Beinabadi and co-authors “confirms the strategic importance of data-driven approaches in creating an ecosystem for the automotive parts industry. The AI-based demand forecasting model developed in the study — a combination of Convolutional Neural Network (CNN) and Recurrent Neural Network (RNN) and the Moth-Flame Optimization (MFO) algorithm — allows for forecasting demand for automotive parts with an accuracy of over 90%.”

Theoretical overview of the forecasting process:

$$\hat{Q}(t+1) = f(CNN, RNN, MFO)$$

Here $\hat{Q}(t+1)$ is the forecast demand for the next period.

The authors then evaluate the efficiency of suppliers using Data Envelopment Analysis (DEA). The model is expressed in the following formula:

$$Efficiency_j = \frac{(\Sigma\, u_r * y_{rj})}{(\Sigma\, v_i * x_{ij})}$$

Here:

- — output indicators (reduction of environmental impact),
- — input resources (energy consumption, cost, etc.).

The process of selecting the optimal supplier through BWM – Best-Worst Method is based on the following formula:

$$Min\ Max \left| \left(\frac{w_B}{w_j}\right) - a_{Bj} \right|, \left| \left(\frac{w_j}{w_W}\right) - a_{jW} \right|$$

Here:

- — best and worst criterion weights,
- — expert ratings.

This scientific approach serves to enhance sustainability, competitiveness and resource efficiency for the automotive industry.

The integration of LCA (Life Cycle Assessment) and LCC (Life Cycle Costing) systems proposed by Carla Simões and co-authors is considered one of the most advanced methods for determining the effectiveness of innovative solutions in the production of automotive parts. This approach allows for a comprehensive assessment of waste, emissions, energy consumption and total costs throughout the entire life cycle of a product, from the stage of raw material selection to disposal.

The production process of spare parts in the automotive industry, in particular auto glass, is characterized by technological complexity, high precision and diversified demand. Traditional efficiency assessment methods are often limited to cost, production volume or simple technical indicators, and cannot cover such modern production elements as innovation, creativity, adaptability to market needs and digital control. Therefore, the development of a creative componential assessment method is necessary and relevant for the formation of a comprehensive assessment of economic efficiency in industrial sectors, especially in the production of automotive spare parts. This method expands the boundaries of traditional indicators and allows integrating new types of creative, innovative and digital factors that affect product quality and production efficiency. As a result, enterprises receive answers not only to the questions “how much was produced”, but also “in what quality, with what technology and to what extent was it produced in accordance with market demand”.

Previously developed evaluation methodologies include analysis based on technical and economic indicators, balance sheet methods, functional cost analysis, ABC/XYZ analysis, and logistics efficiency indices. However, these approaches do not fully reflect the creative-complex evaluation of automotive spare parts, that is, such highly intellectual components as the innovative share, the level of digital control,

energy efficiency, consumer satisfaction, and additional creative profit. This is not enough in modern conditions, since the current automotive industry is being formed on the basis of new paradigms such as “technological transformation”, “digital manufacturing”, “creative designs” and “flexible spare parts chain”. Therefore, the development of the creative component evaluation method fills the gap in existing evaluation concepts: this method combines technical, economic, innovative, and consumer approaches into a single integrated system. The meaning of the componential approach is that each component (cost, defect, innovation, digital control, energy efficiency, CSI, creative profit) affects the overall index with its share, and as a result, the real, comprehensive efficiency of the enterprise is clearly formed.

The cost of one auto glass unit (C_unit) is one of the most important economic criteria indicating the production efficiency of the enterprise. A decrease in the cost indicates an optimized use of resources, technological simplification of production processes, and a decrease in energy and labor consumption. A normalized value above 1.10 indicates a real and significant decrease in costs compared to the base period, which means an increase in production efficiency. This indicator is improved through the introduction of innovative technologies, optimized logistics, waste reduction, and energy efficiency. A decrease in the cost of such delicate and high-quality spare parts as auto glass increases the competitiveness of the enterprise and strengthens its export potential.

The share of defective or unusable products (D_brak) is one of the main indicators that directly reflects quality. The reduction of defectiveness indicates that the quality control system at the enterprise is effectively established, the technological processes are stable, and the personnel are highly qualified. A normalization of this indicator above 1.20 means that the share of defectiveness has been reduced by at least 20 percent, which leads to positive economic results, such as a significant reduction in losses in the production process, cost optimization, and raw material savings. Reducing defectiveness in the production process of auto glass not only increases economic efficiency, but also strengthens quality factors that meet such requirements as safety, optical clarity, and operational durability. The share of innovative auto glass (K_inn) is one of the main indicators that determine the creative potential and level of technological innovation of industrial enterprises. The production of glass with UV-protective, noise-absorbing, energy-saving, or self-healing coatings increases market demand and allows the product to be brought to a higher price segment. If the normalized value of this indicator is 1.20 or higher, this indicates that the share of innovative products at the enterprise has significantly increased and additional economic benefits are being formed through this increase. An increase in the innovative share strengthens the export potential, improves the brand's market position and plays an important role in achieving technological leadership in the automotive industry.

The share of operations covered by digital control (K_raq) reflects the level of technological discipline in the production process. Sensors, video surveillance, online monitoring, digital diagnostics and automatic signaling systems allow for real-time control of the process. A value of this indicator above 1.15 indicates a significant

increase in the share of digital technologies at the enterprise and an improvement in quality, speed and safety indicators. Digital monitoring in the production process of auto glass plays a decisive role in preventing scratches, deformations, thermal loads and defects in the structural strength of glass.

Energy efficiency (K_en) is considered the main component of the cost of auto glass production. The lower the energy consumption, the lower the production costs and the higher the market competitiveness of the product. A normalized index above 1.10 indicates a significant reduction in energy consumption and the introduction of energy-saving technologies at the enterprise - modernization of heat furnaces, automated cutting processes, heat recovery systems. This, along with ensuring economic efficiency, also complies with the principles of environmental sustainability.

The Customer Satisfaction Index (CSI) is a marketing-analytical indicator that shows how well the quality, design, durability and functionality of auto glass meet market demand. An index above 1.10 indicates increased responsiveness to consumer needs, improved advertising and dealer services, and a strengthened brand image. An increase in the CSI indicator increases the share of repurchases, reduces the number of complaints and strengthens the company's position in the market.

CONCLUSION

The assessment of the economic efficiency of innovative activities in the production of automotive spare parts is a complex and strategically significant task that requires methodological approaches extending beyond traditional financial evaluation. The findings of this study confirm that innovation in this sector generates not only direct economic effects, such as cost reduction and productivity growth, but also long-term structural and strategic benefits related to technological sustainability, production flexibility, and competitive positioning within dynamic automotive markets.

The proposed methodological framework demonstrates that an integrated assessment, combining quantitative financial indicators with qualitative performance criteria, provides a more accurate and realistic understanding of innovation efficiency. The use of dynamic evaluation models allows for the consideration of time-lagged effects and cumulative outcomes of innovative activities, which are especially relevant in capital-intensive industrial production. At the same time, qualitative analysis makes it possible to capture critical non-financial results of innovation that significantly influence overall economic performance but are often underestimated in conventional assessments.

The results highlight that comparative and structural analyses are essential for identifying the key drivers of economic efficiency and for distinguishing the real impact of innovation from external market fluctuations. Incorporating risk and sensitivity analysis further enhances the reliability of efficiency assessments by accounting for uncertainty inherent in innovation-driven development.

Overall, the application of comprehensive methods for assessing the economic efficiency of innovative activities enables automotive spare parts manufacturers to make more informed managerial decisions, optimize resource allocation, and align

innovation strategies with long-term development goals. The methodological approaches discussed in this article can serve as a practical analytical basis for enterprises seeking to enhance innovation effectiveness and ensure sustainable economic growth in a highly competitive industrial environment.

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